



# Floristic composition and edaphic influences in the Gulf of Suez, Red Sea Coastal Desert: a comparative study of inland and coastal areas

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## Abstract

This study provides a comparative analysis of plant species composition and distribution between the inland and coastline areas of the Gulf of Suez, Red Sea coastal desert, aiming to enhance understanding of desert plant communities and their relationship with edaphic factors. The study identified 119 plant taxa from 32 families, with the Asteraceae family being the most species-rich, representing 16.8% (20 species), followed by Amaranthaceae (13.4%, 16 species), and Fabaceae, Poaceae, Zygophyllaceae, and Brassicaceae (7.5% each). Coastal areas supported 93 species, while inland areas hosted 73 species. The life form spectrum in the Red Sea coastal desert showed the dominance of Chamaephytes (39.50%) and Therophytes (37.82%) with Phanerophytes (12.61%), Hemicyptophytes (6.72%), Cryptophytes (3.36%) and Parasites (0.84%). Inland areas had a higher proportion of Chamaephytes (46.58%) and Phanerophytes (15.07%), while the coastline had a more balanced distribution, with both Chamaephytes and Therophytes each making up 37.63%. In terms of plant assemblages, coastal regions exhibited seven distinct groupings, such as the *Haloxylon salicornicum* and *Tamarix nilotica* assemblages, while inland regions had five, including assemblages dominated by *Zilla spinosa*, *Launaea spinosa*, and *Farsetia aegyptia*. TWINSpan analysis revealed significant ecological differences between the two regions. Canonical Correspondence Analysis (CCA) indicated that coastal species were primarily influenced by high salinity and ion concentrations, while inland species were more affected by factors like potassium, pH, and calcium carbonate. This study underscores the critical role of understanding these environmental gradients for sustainable management and conservation of Egypt's desert ecosystems.

**Keywords:** CCA; Conservations; Diversity; TWINSpan; Vegetation

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### Introduction

The Eastern Desert of Egypt, covering 21% of the country's total area, is composed of high, rugged mountains running parallel to the coast. It features rugged igneous and limestone mountains, some over 2,000 meters high, and sedimentary plateaus. The Red Sea mountains influence rainfall differently depending on the geological formation: on Eocene limestone, it creates narrow, canyon-like wadis, whereas in Nubian sandstone regions, the flowing water forms broader wadis. The Eastern Desert is extensively dissected by valleys and ravines, with all external drainage systems being Eastward drainage is channeled through numerous independent wadis toward the Red Sea, while westward drainage toward the Nile Valley predominantly merges into a few major trunk channels. The presence of dense wadi networks within the Eastern Desert indicates that, despite the current arid conditions, Egypt likely experienced periods of increased rainfall (pluviation) in its geological history. (Zahran and Wills 2009).

The Eastern Desert of Egypt, divided into two main ecological zones by the Red Sea coastal mountains, highlights the distinct environmental and vegetation dynamics of the Red Sea coastal land and the inland desert. These zones are shaped by diverse topographical and soil features, including saline marshes, gravel plains, and wind-driven deposits, which foster unique plant communities. Vegetation in this area forms a mosaic influenced by seasonal growth cycles, especially the dominance of therophytes during winter and early spring, reflecting the ecological and botanical richness of the region (Zahran and Wills 2009).

Wadis act as natural drainage networks, playing a crucial role in supporting vegetation within the arid coastal desert. They depend on occasional rainfall and groundwater seepage to nurture a variety of plant species, even in the face of challenges like erosion and grazing. Vegetation distribution within wadis is largely determined by soil texture and water flow, creating distinct groupings along the curves of watercourses. Additionally, the floristic composition of the coastal desert is shaped by both environmental conditions and human activities, such as overgrazing and deforestation, highlighting the need to understand these dynamics for successful conservation strategies (El Amier *et al.*, 2015).

The vegetation of the Eastern Desert has been extensively examined by several researchers, including Hassan (1987), Dahmash (2001), Boulos (2008), Abd El-Ghani *et al.* (2014, 2017), and Salama *et al.* (2018). However, comparative studies addressing the differences between inland and coastal vegetation are relatively limited. Key studies in this area include those by Zahran and Wills (2009) and EL-Amier *et al.* (2016). Zahran and Wills (2009) documented significant variations in plant communities between the inland and coastal deserts of the Red Sea, illustrating how differing environmental

conditions impact vegetation distribution. Similarly, EL-Amier et al. (2015) conducted a comparative analysis of vegetation along the Deltaic Mediterranean coastal desert and the Cairo-Suez Desert Road, focusing on the distinct plant species found in these regions. This study aims to extend these investigations by examining the floristic composition of the primary vegetation groups in representative areas of the Gulf of Suez, covering both the inland and coastal deserts of the Red Sea. Additionally, the study seeks to assess the relationship between these vegetation groups and their soil properties, providing insights into the environmental variables that influence plant distribution and diversity in these challenging ecosystems. This will contribute to understanding the historical and ongoing evolution of vegetation communities in the region.

## Materials and Methods

### Study area

The study area lies within the Gulf of Suez in the northern part of the Red Sea coastal desert of Egypt, encompassing both coastal and inland desert regions and spanning approximately 3,548 km<sup>2</sup>. The area is characterized by diverse geomorphological features, including extensive sandy shores, rugged mountainous terrains, wadis, and rocky plateaus. A total of 60 collection sites were studied, comprising 30 along the coastline and 30 in the inland desert. The coastline sites include Wadi El-Gamil, Wadi El-Ramliya, the end of Wadi Hagul, Ain Sokhna, Wadi Amlog, in front of Gabal Um Rosis, Wadi Ghweiba, Wadi Abu Dahab, in front of Gabal Masama, near Ras Abu Darag, and Wadi Malaha. The inland sites include Wadi Hemra, Cairo-Suez Road, Wadi Hagul, Wadi El-Bada, and between Wadi El-Bada and Gabal Um Zeita (Map 1). These sites represent a variety of habitats influenced by environmental gradients such as soil type, water availability, and proximity to the sea, making the area a significant focus for studying vegetation distribution and its relationship with edaphic factors in arid ecosystems.

The study area experiences a **subtropical desert climate** characterized by arid and hot conditions. The monthly average temperatures fluctuate between seasons, with summer reaching a peak average of **35.3°C** and winter dropping to a low average of **15.3°C**. Rainfall is most abundant in the winter months, averaging **5 mm**, whereas spring and summer receive minimal precipitation. According to the **Köppen-Geiger climate classification (BWh)** and the **Holdridge life zones bioclimatic system**, this region falls within an arid desert climate category (<http://www.suez.climatemps.com>; accessed on 31/8/2023).

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**Map 1.** Location for the collection sites in the study area along the Gulf of Suez, Red Sea coast. **Coastal sites (1–30)** include Wadi El-Gamil (1 & 2, 12 & 13), Wadi El-Ramliya (3 & 4), areas between Wadi Hagul and Wadi El-Ramliya (14), Wadi Hagul (6, 7, 15, 16, 22, 23), Ain Shokna (8, 17), Wadi Amlog (9, 19), Wadi El-Bada (10), in front of Gabal Moghra Bahria (11), in front of Gabal Um Rosis (18, 20), between Gabal El-Akheider and Wadi Ghweiba (21), Wadi Abu Dahab (24), in front of Gabal Masama (25), near Ras Abu Darag (26 & 27), Ras Abu Darag (28 & 29), and Wadi Malaha (30); **Inland sites (31–60)** include Wadi Hemra (31), Cairo-Suez Road (32 & 33), Wadi Hagul (34–50), Wadi El-Bada (51–59), and in front of Gabal El-Ramliya (60).

As described by Zahran and Willis (2009), the desert landscape surrounding the Red Sea is characterized by diverse geomorphological features, including limestone plateaus and rugged igneous mountain ranges. Along the west coast of the Gulf of Suez, these coastal mountains include notable formations such as Gebel Ataqa (817 m), Gebel El-Galala El-Bahariya (977 m), and the Gebel Shayeb El-Banat group, which features peaks rising over 1,700 meters, including the highest point, Gebel Shayeb El-Banat (2,187 m). These mountain ranges significantly influence the hydrology and vegetation distribution of the region. Between these mountains and the coastline lies a gently sloping plain, known as the deep plain. This coastal plain, varying in width, is covered with sand and traversed by drainage systems (wadis). These wadis flow eastward, carrying water through their shallow channels into the Red Sea and the Gulf of Suez.

## **Materials**

### Plant Collection

Plant specimens were collected from the 60 sites studied using belt transect sampling. The fieldwork was carried out between 2022 and 2024 within the Gulf of Suez, Red Sea coastal desert. The GPS coordinates were obtained with a Megellan GPS 315 handheld device for the collected plant specimens.

### Soil Samples Collection

Sixty soil samples were collected from three locations at each collection site in plastic bags. These samples were collected from a depth of 0–30 cm using a clean shovel to avoid contamination.

## **Methods**

### Morphological Examination

Detailed morphological and micromorphological descriptions were carried out for critical species needing accurate identification. These descriptions were based on previous work by Boulos (1999, 2000, 2002, 2005). Vegetative parts were examined under a binocular stereoscopic microscope and mounted on slides using a glycerin jelly-water medium. All specimens were preserved in the Suez Canal University Herbarium (SCU-I).

### Identification of Plant Specimens

Plant specimens were identified using reference works by Boulos (1999, 2000, 2002, 2005) and Täckholm (1974). Comparisons were made with herbarium sheets from SCU-I and floras from neighboring countries (e.g., Zohary and Feinbrun-Dothan, 1966; Migahid, 1978). Recent valid names were verified using international databases (IPNI, POWO). The geographical distribution in Egypt and globally was referenced by Boulos (2009).

## **Soil Analysis**

### Physical Analysis of Soil

The pipette method, as stated by Tributh (1970), was used to determine the particle size distribution. The Walkley and Black method, as stated by Jackson (1967), was used to determine organic matter and organic carbon.

### **Soil Chemical Analysis**

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The conductivity meter model Jenway 3310 was used to test the saturated soil paste extract's electrical conductivity (EC) according to Richards (1954). The soil pH was measured in 1:2.5 soil water suspensions using a bench type Beckman glass electrode pH meter (Page et al. 1982). According to Page et al., (1982), the Ethylene diamine tetra acetic acid (EDTA) volumetric titration was used to extract calcium and magnesium from the saturated soil. and a flame photometer was used to measure potassium and sodium, while the bicarbonate was tested by titrating with sulfuric acid, and chloride was determined by titrating with silver nitrate. Finally, the total carbonates was calculated using Collin's calcimeter (Piper, 1950).

### Quantitative Vegetation Analysis

The phytosociological data from the studied 60 sites and the collected 119 species were analyzed using the TWINSpan (Two-way Indicator Species Analysis) technique in the PC-ORD program. Canonical Correspondence Analysis (CCA) was used to explore species/environment relationships and sort species and samples along environmental gradients in this study. It facilitated an understanding of how plant species distributions correlate with soil and other environmental variables across the Gulf of Suez inland and coastal regions.

### Results

The field survey in the studied 60 sites revealed the identification of 119 species (108 dicots and 11 monocots), encompassing 9 subspecies. These species represent 32 families and 87 genera of vascular plants. The vegetation was categorized into three trees, 12 shrubs, 74 perennials, 2 biennials, and 43 annuals. The Asteraceae family was the most species-rich with 20 species (16.8%), followed by Amaranthaceae with 16 species (13.4%) then Fabaceae, Poaceae, Zygophyllaceae, and Brassicaceae (7.5%), respectively. Following these, Solanaceae included 6 species and 4 species in each of Boraginaceae and Apocynaceae. Families with fewer species included Tamaricaceae (3 species), Convolvulaceae (3 species), Cucurbitaceae (2 species), and Capparaceae (2 species). Moreover, 15 families were monogeneric including Caryophyllaceae, Ephedraceae, and Plumbaginaceae. These results highlight the taxonomic richness and diversity of the plant communities in the whole study area Table (1).

The floristic composition of the study area revealed distinct patterns of species distribution between the coastline and inland regions, with the Asteraceae family being the most species-rich including 15 and 17 species along the coastline inland sites; respectively. While, Amaranthaceae was in the second position, with 14 and 7 species on the coastline and inland sites; respectively, indicating a species richness in the coastal habitats. The Poaceae

family also shows significant variation, with 8 species found on the coastline and 4 on inland sites while Zygophyllaceae is another prominent family, with 9 species on the coastline and 8 inland showcasing its dominance in both coastal and inland sites. Brassicaceae included 4 species on the coastline and 2 inland but Solanaceae represented 6 species on the coastline and only one in the inland demonstrating a higher species richness on the coastline and a sharp decline inland. On the other hand, the floristic composition of the study area reveals a clear division of plant families, with several species restricted either to the coastline or the inland. A total of 8 families were found exclusively in the sites along the coastline: Juncaceae, Malvaceae, Plumbaginaceae, Portulacaceae, Plantaginaceae, Primulaceae, Areaceae, and Urticaceae. Conversely, 6 families were restricted to the inland region: Caryophyllaceae, Ephedraceae, Lamiaceae, Orobanchaceae, Rutaceae, and Scrophulariaceae (Figure 1 or 2).

The species composition exhibited notable differences between the coastline and inland areas. The coastline contained 93 species, including *Lepidium didymum*, *Convolvulus hystrix*, *Euphorbia peplus*, *Rumex spinosus*, and *Forsskaolea tenacissima*. In contrast, the inland areas supported 73 species, such as *Matthiola longipetala*, *Gymnocarpos decander*, *Ephedra alata*, *Euphorbia retusa*, *Lavandula coronopifolia*, and *Tricholaena teneriffae*. Furthermore, 48 species were shared between both areas, including *Bassia eriophora*, *Deverra tortuosa*, *Pulicaria incisa*, *Hyoscyamus boveanus*, and *Tribulus mollis*.

The life form spectrum of the study area displayed notable variations. Chamaephytes were the most dominant life form, comprising 39.50% of the total, followed closely by therophytes, which made up 37.82%. They were followed by phanerophytes, which represented 12.61%, and hemicryptophytes and cryptophytes, which accounted for 6.72% and 3.36%, respectively. Parasites were the least represented, contributing only 0.84%.

In comparing the inland and coastline regions, there were notable differences in the distribution of life forms. In the inland area, chamaephytes were the most dominant life form, comprising 46.58% (34 out of 73 species), followed by Therophytes representing 26.03% (19 out of 73 species). Then phanerophytes contributed 15.07%, Hemicryptophytes made up 8.22%, cryptophytes 2.74% and parasites were the least represented with 1.37%. In contrast, the coastline area showed equal prevalence in Therophytes and Chamaephytes percentages 37.63%. Phanerophytes represented 12.90% while Hemicryptophytes made up 7.53% and cryptophytes comprised 4.30%. Parasites were absent from the coastline region (Figure 2, Table 1).

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**Table 1.** List of recorded species in the study area, life forms, habitats, and geographical distribution. Note: Duration: Ann=annual, Bi=biennial, Per = perennial. Life form: Th=Therophytes, H= Hemicryptophytes, Ph= phanerophytes, Ch= chamaephytes, C= Cryptophytes, P=Parasites, (+ = recorded, - = not recorded)

| Family                         | species   | Habit | Life form | Coastal sites | Inland sites |
|--------------------------------|---|-------|-----------|---------------|--------------|
| <b>Amaranthaceae</b>           | <i>Amaranthus viridis</i> L.                                      | Ann   | Th        | +             | -            |
|                                | <i>Anabasis articulata</i> (Forssk.) Moq.                         | Per   | Ch        | -             | +            |
|                                | <i>A. setifera</i> Moq.   |       |           | +             | +            |
|                                | <i>Arthrocaulon macrostachyum</i> (Moric.) Pirainen & G. Kadereit | Per   | Ch        | +             | -            |
|                                | <i>Atriplex humilis</i> F.Muell                                   | Per   | Ch        | -             | +            |
|                                | <i>Bassia eriophora</i> (Schrad.) Asch.                           | Ann   | Th        | +             | +            |
|                                | <i>B. indica</i> (Wight) A.J.Scott                                | Ann   | Th        | +             | -            |
|                                | <i>Caroxylon imbricatum</i> (Forssk.) Moq.                        | Per   | Ph        | +             | -            |
|                                | <i>Chenopodium album</i> L.                                       | Ann   | Th        | +             | -            |
|                                | <i>C. ficifolium</i> Sm.  | Ann   | Th        | +             | -            |
|                                | <i>C. murale</i> L.   | Ann   | Th        | +             | -            |
|                                | <i>Halopeplis perfoliata</i> (Forssk.) Bunge ex Ung.-Sternb.      | Ann   | Th        | +             | -            |
|                                | <i>Haloxylon persicum</i> Bunge                                   | Per   | Ph        | +             | +            |
|                                | <i>H. salicornicum</i> (Moq.) Bunge ex Boiss.                     | Per   | Ch        | +             | +            |
|                                | <i>H. scoparium</i> pomel.  | Per   | Ch        | +             | -            |
| <i>Traganum nudatum</i> Delile | Per   | Ch    | +         | +             |              |



|                    |   |     |    |   |   |
|--------------------|---|-----|----|---|---|
| <b>Apiaceae</b>    | <i>Deverra tortuosa</i> (Desf.) DC.                                   | Per | Ch | + | + |
| <b>Apocynaceae</b> | <i>Calotropis procera</i> (Aiton)<br>W.T.Aiton.                       | Per | Ch | + | - |
|                    | <i>Cynanchum acutum</i> L. subsp. <i>acutum</i>                       | Per | H  | + | - |
|                    | <i>Leptadeniapyrotechnica</i> (Forssk.)<br>Decne.                     | Per | Ph | + | + |
|                    | <i>Pergularia tomentosa</i> L.  | Per | Ch | + | + |
| <b>Areaceae</b>    | <i>Phoenix dactylifera</i> L.   | Per | Ph | + | - |
| <b>Asteraceae</b>  | <i>Achillea fragrantissima</i> (Forssk.)<br>Sch.Bip.                  | Per | Ch | + | + |
|                    | <i>Artemisia judaica</i> L.   | Per | Ch | - | + |
|                    | <i>Brocchia cinerea</i> (Delile) Vis.                                 | Ann | Th | - | + |
|                    | <i>Centaurea aegyptiaca</i> L.  | Bi  | Th | - | + |
|                    | <i>Echinops spinosus</i> L.   | Per | H  | + | + |
|                    | <i>Erigeron bonariensis</i> L.  | Ann | Th | + | - |
|                    | <i>Ifloga spicata</i> (Forssk.) Sch.Bip.<br>subsp. <i>spicata</i>     | Ann | Th | - | + |
|                    | <i>Iphiona mucronata</i> (Forssk.) Asch. &<br>Schweinf.               | Per | Ch | + | + |
|                    | <i>Launaea mucronata</i> (Forssk.)<br>Muschl. subsp. <i>mucronata</i> | Ann | Th | + | + |
|                    | <i>L. nudicaulis</i> (L.) Hook.f.                                     | Per | H  | + | + |
|                    | <i>L. procumbens</i> (Roxb.) Ramayya &<br>Rajagopal                   | Ann | Th | - | + |
|                    | <i>L. spinosa</i> (Forsk.) Sch.Bip.ex Kuntze                          | Per | Ch | + | + |
|                    | <i>Nidorella aegyptiaca</i> (L.)<br>J.C.Manning & Goldblatt.          | Ann | Th | + | + |
|                    | <i>Pluchea dioscoridis</i> (L.) DC.                                   | Per | Ph | + | + |
|                    | <i>Pulicaria incisa</i> (Lam.) DC.                                    | Per | Ch | + | + |

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|                      |  |     |    |   |   |
|----------------------|--|-----|----|---|---|
|                      | <i>P. undulata</i> (L.) C. A. Mey. subsp. <i>undulata</i>                            | Per | Ch | + | + |
|                      | <i>Reichardia tingitana</i> (L.) Roth  | Ann | Th | + | - |
|                      | <i>Senecio glaucus</i> L. subsp. <i>coronopifolius</i> (Maire.) C. Alexander.        | Ann | Th | + | + |
|                      | <i>Sonchus oleraceus</i> L.  | Ann | Th | + | + |
|                      | <i>Urospermum picroides</i> (L.) F.W. Schmidt.                                       | Ann | Th | + | - |
| <b>Boragoniaceae</b> | <i>Heliotropium arbainense</i> Fresen.   | Per | Ch | - | + |
|                      | <i>H.bacciferum</i> Forssk. var. <i>bacciferum</i>                                   | Per | Ch | + | - |
|                      | <i>H. digynum</i> (Forssk.) Christens  | Per | Ch | - | + |
|                      | <i>Trichodesma africanum</i> (L.) Sm.  | Ann | Th | + | - |
| <b>Brassicaceae</b>  | <i>Anastatica hierochuntica</i> L.   | Ann | Th | - | + |
|                      | <i>Coincya tournefortii</i> (Gouan) Alcaraz, T.E.Díaz, Rivas Mart. & Sánchez-Gómez   | Ann | Th | + | - |
|                      | <i>Diplotaxis acris</i> (Forssk.) Boiss.   | Ann | Th | - | + |
|                      | <i>Eremobium aegyptiacum</i> (Spreng.)<br>Asch. var. <i>aegyptiacum</i>              | Bi  | Th | - | + |
|                      | <i>Farsetia aegyptia</i> Turra, Farset.  | Per | Ch | + | + |
|                      | <i>Lepidium didymum</i> L.   | Ann | Th | + | - |
|                      | <i>Matthiola longipetala</i> (Vent.)<br>DC.subsp. <i>bicornis</i> (Sm.) P.W. Ball.   | Ann | Th | - | + |
|                      | <i>Matthiola longipetala</i> (Vent.)<br>DC. subsp. <i>livida</i> (Delile.) Maire DC. | Ann | Th | - | + |
|                      | <i>Zilla spinosa</i> (L.) Prantl.  | Per | Ch | + | + |
| <b>Capparaceae</b>   | <i>Cleome amblyocarpa</i> Barratte & Murb.   | Ann | Th | + | + |
|                      | <i>C. droserifolia</i> (Forssk.) Delile  | Per | Ch | + | + |

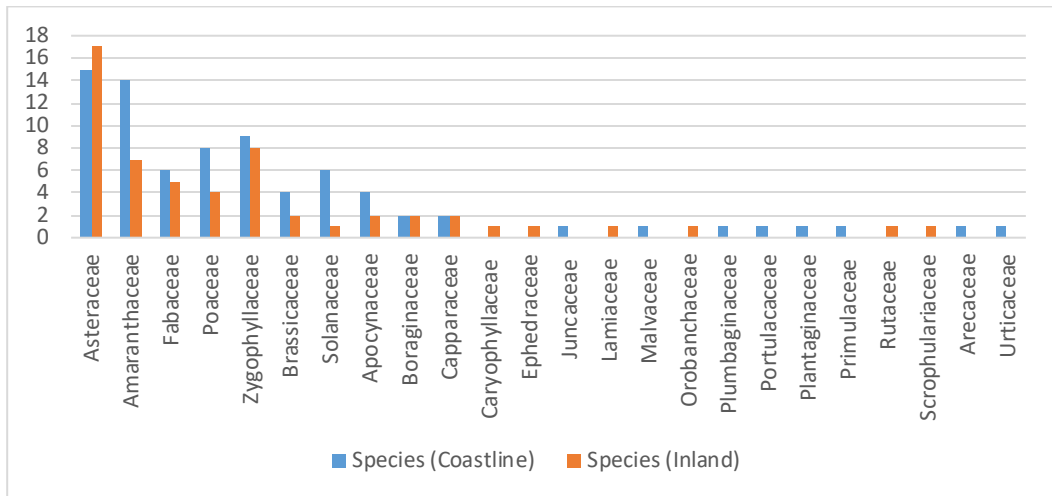
|                        |   |     |    |   |   |
|------------------------|---|-----|----|---|---|
| <b>Caryophyllaceae</b> | <i>Gymnocarpus decander</i> Forssk.                                     | Per | Ch | - | + |
| <b>Convolvulaceae</b>  | <i>Convolvulus hystrix</i> Vahl.  | Per | Ch | + | - |
|                        | <i>C.lanatus</i> Vahl.  | Per | Ch | + | + |
|                        | <i>Ipomoea pes-caprae</i> (L.) R.Br.                                    | Per | H  | + | - |
| <b>Cucurbitaceae</b>   | <i>Citrullus colocynthis</i> (L.) Schrad.                               | Per | H  | + | + |
|                        | <i>Cucumis melo</i> L.  | Ann | Th | + | - |
| <b>Ephedraceae</b>     | <i>Ephedra alata</i> Decne.   | Per | Ch | - | + |
| <b>Euphorbiaceae</b>   | <i>Euphorbia peplus</i> L.  | Ann | Th | + | - |
|                        | <i>Euphorbia retusa</i> (L.) Forssk.                                    | Per | Ch | - | + |
| <b>Fabaceae</b>        | <i>Alhagi graecorum</i> Boiss.  | Per | Ch | + | - |
|                        | <i>Astragalus spinosus</i> (Forssk.) Muschl.                            | Per | Ch | + | - |
|                        | <i>A. sieberi</i> DC.   | Per | Ch | - | + |
|                        | <i>Crotalaria aegyptiaca</i> Benth.                                     | Per | Ch | + | + |
|                        | <i>Melilotus indicus</i> (L.) All.                                      | Ann | Th | + | - |
|                        | <i>Retama raetam</i> (Forssk.) Webb & Berthel.                          | Per | Ph | - | + |
|                        | <i>Taverniera aegyptiaca</i> Boiss.                                     | Per | Ch | + | - |
|                        | <i>Vachellia tortilis</i> subsp. <i>raddiana</i> (Savi) Kyal. & Boatwr. | Per | Ph | - | + |
|                        | <i>Vachellia tortilis</i> (Forssk.) Galasso & Banfi                     | Per | Ph | + | + |
| <b>Juncaceae</b>       | <i>Juncus rigidus</i> Desf.   | Per | C  | + | - |
| <b>Lamiaceae</b>       | <i>Lavandula coronopifolia</i> Poir.                                    | Per | Ch | - | + |
| <b>Malvaceae</b>       | <i>Malva parviflora</i> L.  | Ann | Th | + | - |
| <b>Nitrariaceae</b>    | <i>Nitraria retusa</i> (Forssk.) Asch.                                  | Per | Ph | + | + |
| <b>Orobanchaceae</b>   | <i>Cistanche tubulosa</i> (Schenk) Wight ex Hook.f var. <i>tubulosa</i> | Per | P  | - | + |

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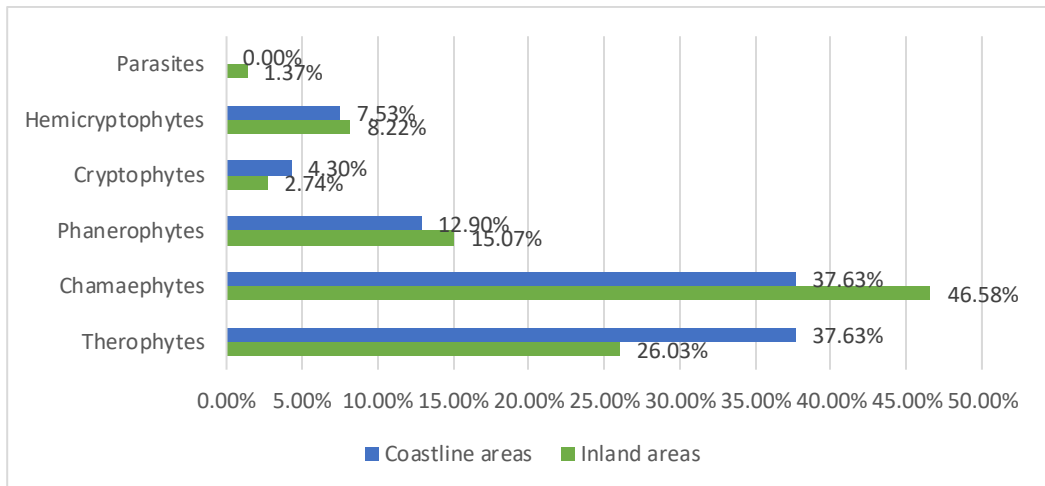
|                         |   |     |    |   |   |
|-------------------------|---|-----|----|---|---|
| <b>Plumbaginaceae</b>   | <i>Limonium pruinatum</i> (L.) Chaz.                          | Per | Ch | + | - |
| <b>Poaceae</b>          | <i>Cenchrus biflorus</i> Roxb.                                | Ann | Th | + | - |
|                         | <i>C. divisus</i> (J.F.Gmel.) Verloove,<br>Govaerts & Buttler | Per | Ch | + | - |
|                         | <i>Cynodon dactylon</i> (L.) Pers.                            | Per | C  | + | - |
|                         | <i>Diplachne fusca</i> (L.) P.Beauv. ex<br>Roem. & Schult.    | Per | Ch | + | - |
|                         | <i>Imperata cylindrica</i> (L.) Raeusch.                      | Per | C  | + | + |
|                         | <i>Lasiurus scindicus</i> Henrard.                            | Per | H  | + | + |
|                         | <i>Panicum turgidum</i> Forssk.                               | Per | H  | + | + |
|                         | <i>Phragmites australis</i> (L.) (Cav.) Trin.<br>ex. Steud.   | Per | C  | + | + |
|                         | <i>Tricholaena teneriffae</i> (L.f.) Link                     | Per | H  | - | + |
| <b>Polygonaceae</b>     | <i>Rumex spinosus</i> L.                                      | Ann | Th | + | - |
|                         | <i>R. vesicarius</i> L.                                       | Ann | Th | + | + |
| <b>Portulacaceae</b>    | <i>Portulaca oleracea</i> L.                                  | Ann | Th | + | - |
| <b>Plantaginaceae</b>   | <i>Plantago ovata</i> Forssk.                                 | Ann | Th | + | - |
| <b>Primulaceae</b>      | <i>Lysimachia arvensis</i> (L.) U.Manns &<br>Anderb.          | Ann | Th | + | - |
| <b>Resedaceae</b>       | <i>Caylusea hexagyna</i> (Forssk.)<br>M.L.Green               | Ann | Th | - | + |
|                         | <i>Ochradenus baccatus</i> Delile                             | Per | Ph | + | + |
|                         | <i>Reseda pruinosa</i> Delile                                 | Ann | Th | + | - |
| <b>Rutaceae</b>         | <i>Haplophyllum tuberculatum</i> (Forssk.)<br>A. Juss.        | Per | Ch | - | + |
| <b>Scrophulariaceae</b> | <i>Kickxia aegyptiaca</i> (L.) Nábělek                        | Per | Ch | - | + |
| <b>Solanaceae</b>       | <i>Lycium shawii</i> Roem. & Schult.                          | Per | Ph | + | + |

|                       |   |     |    |           |           |
|-----------------------|---|-----|----|-----------|-----------|
|                       | <i>Hyoscyamus boveanus</i> (Dunal.) Asch. & Schweinf. | Per | Ch | +         | +         |
|                       | <i>H. desertorum</i> (Asch. ex Boiss.) Täckh.         | Ann | Th | +         | -         |
|                       | <i>H. muticus</i> L.                                  | Per | Ch | +         | -         |
|                       | <i>Solanum lycopersicum</i> L.                        | Ann | Th | +         | -         |
|                       | <i>S. nigrum</i> L.                                   | Ann | Th | +         | -         |
| <b>Tamaricaceae</b>   | <i>Tamarix aphylla</i> (L.) H. Karst.                 | Per | Ph | +         | -         |
|                       | <i>T. nilotica</i> (Ehrenb.) Bunge.                   | Per | Ph | +         | +         |
|                       | <i>T. tetragyna</i> Ehrenb.                           | Per | Ph | +         | +         |
| <b>Urticaceae</b>     | <i>Forsskaolea tenacissima</i> L.                     | Per | Ch | +         | -         |
| <b>Zygophyllaceae</b> | <i>Tribulus mollis</i> Ehrenb. ex Schweinf.           | Ann | Th | +         | +         |
|                       | <i>T. terrestris</i> L.                               | Ann | Th | +         | -         |
|                       | <i>Zygophyllum album</i> L.                           | Per | Ch | +         | +         |
|                       | <i>Z. arabicum</i> (L.) Christenh. & Byng             | Per | Ch | +         | +         |
|                       | <i>Z. bruguieri</i> (DC.) Christenh. & Byng           | Per | Ch | +         | +         |
|                       | <i>Z. coccineum</i> L.                                | Per | Ch | +         | +         |
|                       | <i>Z. decumbens</i> Delile                            | Per | Ch | +         | +         |
|                       | <i>Z. molle</i> (Delile) Christenh. & Byng            | Per | Ch | +         | +         |
|                       | <i>Z. Simplex</i> L.                                  | Ann | Th | +         | +         |
| <b>Total</b>          | <b>119</b>  |     |    | <b>93</b> | <b>73</b> |

## Floristic Composition and Edaphic Influences in the Gulf of Suez



**Fig. 1.** The difference between families on the coastline and inland areas



**Fig. 2.** The life difference between the coastline and inland areas

TWINSPAN analysis categorized the collection sites in the coastal areas into seven distinct assemblages: *Haloxylon salicornicum* assemblage, *Zygophyllum coccineum* assemblage, *Zygophyllum coccineum*–*Ochradenus baccatus*–*Bassia indica* assemblage, *Trichodesma africanum*–*Zygophyllum coccineum* assemblage, *Tamarix nilotica* assemblage, *Tamarix nilotica* assemblage, and *Tamarix aphylla* assemblage. The presence percentages of species composition for these assemblages are detailed in Table (2). The first assemblage was dominated by *Haloxylon salicornicum* with 100% presence and an average abundance of 2.5. It was followed by the codominant species *Ochradenus*

*baccatus* (75%, 2.6 average abundance) and the associated species *Zygophyllum coccineum* (50%, 3.0). In the second assemblage, *Zygophyllum coccineum* was the dominant species, with 100% presence and an average abundance of 3.16. Codominant species included *Ochradenus baccatus* (83.3%, 3.0), *Zilla spinosa* (83.3%, 3.8), and *Calotropis procera* (83.3%, 2.8). Associated species such as *Leptadenia pyrotechnica* (66.64%, 2.25), *Convolvulus hystrix* (49.98%, 3.33), and *Hyoscyamus muticus* (49.98%, 2.33) were also identified. The third assemblage was characterized by three dominant species: *Zygophyllum coccineum* (74.2%, 3.66), *Ochradenus baccatus* (74.2%, 2.66), and *Bassia indica* (74.2%, 3.0). Codominant species included *Zilla spinosa* and *Tamarix nilotica* each with 66.66% presence and average abundances of 3.0 and 3.5, respectively. The fourth assemblage had two dominant species: *Trichodesma africanum* and *Zygophyllum coccineum* both with 100% presence and average abundances of 3.0 and 4.0, respectively. The codominant species *Tamarix nilotica* exhibited 75% presence and an average abundance of 3.0, while *Farsetia aegyptia* was the associated species, with 50% presence and an average abundance of 4.0. The fifth assemblage was dominated by *Tamarix nilotica* with 100% presence and an average abundance of 3.28. The codominant species *Phargmites australis* had 71.42% presence and an average abundance of 3.0, while *Nitraria retusa* represented the associated species (57.12%, 2.0). In the sixth assemblage, *Tamarix nilotica* was again the dominant species, with 100% presence and an average abundance of 4.0. Codominant species included *Phargmites australis* (75%, 3.33) and *Zygophyllum coccineum* (75%, 3.66). Associated species were *Bassia indica*, *Chenopodium murale*, *Portulaca oleracea*, and *Sonchus oleraceus* all with 75% presence and average abundances of 3.0, 4.0, 2.0, and 4.0, respectively. Finally, the seventh assemblage was dominated by *Tamarix aphylla* with 100% presence and an average abundance of 2.0.

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**Table 2.** The phytosociological table shows the presence percentage and average abundance for coastline sites' main assemblages resulting from TWINSpan classification. Avg=Average abundance, P =Presence

| Group<br>Species                  | I  |      | II   |      | III |      | IV    |      | V     |      | VI |      | VII |      | Species<br>Abbreviations |
|-----------------------------------|----|------|------|------|-----|------|-------|------|-------|------|----|------|-----|------|--------------------------|
|                                   | 4  |      | 6    |      | 3   |      | 4     |      | 7     |      | 4  |      | 2   |      |                          |
|                                   | P  | Avg  | P    | Avg  | P   | Avg  | P     | Avg  | P     | Avg  | P  | Avg  | P   | Avg  |                          |
| <i>Achillea fragrantissima</i>    |    |      | 33.2 | 2.00 |     |      |       |      |       |      |    |      |     |      | Achi fra                 |
| <i>Alhagi graecorum</i>           |    |      |      |      |     |      |       |      | 42.84 | 3.00 |    |      |     |      | Alha gra                 |
| <i>Anabasis setifera</i>          | 25 | 2.00 |      |      |     |      |       |      | 14.28 | 1.0  |    |      |     |      | Anab seti                |
| <i>Arthrocaulon macrostachyum</i> |    |      | 16.6 | 1.00 |     |      | 25    | 3.00 |       |      |    |      |     |      | Arth mac                 |
| <i>Astragalus spinosus</i>        |    |      |      |      |     |      |       |      |       |      | 25 | 2.00 | 50  | 2.00 | Astr spi                 |
| <i>Astragalus sieberi</i>         |    |      |      |      |     |      |       |      | 14.28 | 1.0  |    |      |     |      | Astr sie                 |
| <i>Bassia eriophora</i>           |    |      |      |      |     |      |       |      |       |      | 25 | 2.00 |     |      | Bass eri                 |
| <i>Bassia indica</i>              |    |      |      |      | 100 | 3.00 |       |      |       |      | 50 | 3.00 |     |      | Bass ind                 |
| <i>Calotropis procera</i>         |    |      | 83.3 | 2.8  | 25  | 1.00 | 14.28 | 2.00 |       |      |    |      |     |      | Calo pro                 |
| <i>Caroxylon imbricatum</i>       |    |      | 16.6 | 2.00 |     |      |       |      |       |      |    |      |     |      | Caro imb                 |
| <i>Cenchrus biflorus</i>          |    |      |      |      |     |      |       |      |       |      | 25 | 2.00 |     |      | Cenc bif                 |
| <i>Cenchrus divinus</i>           |    |      |      |      |     |      | 25    | 2.00 |       |      |    |      |     |      | Cenc div                 |
| <i>Chenopodium album</i>          |    |      |      |      |     |      |       |      |       |      | 25 | 2.00 |     |      | Chen alb                 |
| <i>Chenopodium ficifolium</i>     |    |      |      |      |     |      |       |      |       |      | 25 | 2.00 |     |      | Chen fic                 |
| <i>Chenopodium murale</i>         |    |      |      |      |     |      |       |      |       |      | 50 | 4.00 |     |      | Chen mur                 |



|                                |            |             |              |             |             |             |             |              |              |            |             |  |  |                  |
|--------------------------------|------------|-------------|--------------|-------------|-------------|-------------|-------------|--------------|--------------|------------|-------------|--|--|------------------|
| <i>Citrullus colocynthis</i>   |            |             | <b>33.2</b>  | <b>2.00</b> |             |             |             |              |              |            |             |  |  | <b>Citr col</b>  |
| <i>Cleome amblyocarpa</i>      |            |             | <b>33.2</b>  | <b>3.00</b> |             |             |             |              |              |            |             |  |  | <b>Cleo amb</b>  |
| <i>Cleome droserifolia</i>     |            |             |              |             |             |             |             | <b>14.28</b> | <b>1.00</b>  |            |             |  |  | <b>Cleo dro</b>  |
| <i>Coincya tournefortii</i>    |            |             |              |             |             | <b>25</b>   | <b>2.00</b> |              |              |            |             |  |  | <b>Coin tou</b>  |
| <i>Convolvulus hystrix</i>     |            |             | <b>66.64</b> | <b>2.25</b> |             |             |             |              |              |            |             |  |  | <b>Conv hys</b>  |
| <i>Convolvulus lanatus</i>     |            |             |              |             |             |             |             | <b>14.28</b> | <b>1.00</b>  |            |             |  |  | <b>Conv lan</b>  |
| <i>Crotalaria aegyptiaca</i>   | <b>25</b>  | <b>2.00</b> | <b>16.6</b>  | <b>3.00</b> |             |             |             |              |              |            |             |  |  | <b>Crot aeg</b>  |
| <i>Cucumis melo</i>            |            |             |              |             | <b>33.3</b> | <b>1.00</b> |             |              |              |            |             |  |  | <b>Cucu mel</b>  |
| <i>Cynanchum acutum</i>        |            |             |              |             | <b>33.3</b> | <b>3.00</b> |             | <b>14.28</b> | <b>1.0</b>   | <b>25</b>  | <b>2.00</b> |  |  | <b>Cyna acu</b>  |
| <i>Cynodon dactylon</i>        |            |             |              |             |             |             | <b>25</b>   | <b>3.00</b>  |              | <b>25</b>  | <b>2.00</b> |  |  | <b>Cyno dac</b>  |
| <i>Deverra tortuosa</i>        |            |             |              |             |             |             |             | <b>14.28</b> | <b>1.0</b>   |            |             |  |  | <b>Deve tor</b>  |
| <i>Diplachne fusca.</i>        |            |             |              |             |             |             | <b>25</b>   | <b>1.00</b>  |              |            |             |  |  | <b>Dipl acr</b>  |
| <i>Echinops spinosus</i>       | <b>25</b>  | <b>3.00</b> |              |             |             |             |             | <b>28.56</b> | <b>2.0</b>   |            |             |  |  | <b>Echi spi</b>  |
| <i>Erigeron bonariensis</i>    |            |             |              |             |             |             |             |              |              | <b>25</b>  | <b>2.00</b> |  |  | <b>Erig bon</b>  |
| <i>Euphorbia peplus</i>        |            |             |              |             |             |             |             |              |              | <b>25</b>  | <b>2.00</b> |  |  | <b>Euph pep</b>  |
| <i>Farsetia aegyptia</i>       | <b>25</b>  | <b>2.00</b> | <b>16.6</b>  | <b>3.00</b> |             |             | <b>50</b>   | <b>4.00</b>  |              |            |             |  |  | <b>Fars aeg</b>  |
| <i>Halopeplis perfoliata</i>   |            |             |              |             |             |             |             | <b>14.28</b> | <b>2.00</b>  |            |             |  |  | <b>Halo per</b>  |
| <i>Haloxylon persicum</i>      |            |             |              |             |             |             |             |              |              | <b>25</b>  | <b>4.00</b> |  |  | <b>Halo sal</b>  |
| <i>Haloxylon salicornicum</i>  | <b>100</b> | <b>2.5</b>  | <b>33.2</b>  | <b>2.5</b>  |             |             | <b>25</b>   | <b>2.00</b>  | <b>14.28</b> | <b>1.0</b> |             |  |  | <b>Halo sco</b>  |
| <i>Haloxylon scoparium</i>     | <b>100</b> | <b>2.00</b> |              |             |             |             |             |              |              |            |             |  |  | <b>Halop per</b> |
| <i>Heliotropium bacciferum</i> |            |             |              |             | <b>33.3</b> | <b>2.00</b> |             |              |              |            |             |  |  | <b>Heli bac</b>  |

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|                                |    |      |       |      |      |      |      |       |       |     |      |    |      |  |          |
|--------------------------------|----|------|-------|------|------|------|------|-------|-------|-----|------|----|------|--|----------|
| <i>Hyoscyamus boveanus</i>     |    |      | 16.6  | 3.00 |      |      |      |       |       |     |      |    |      |  | Hyos bov |
| <i>Hyoscyamus desertorum</i>   |    |      | 33.2  | 3.00 |      |      |      |       |       |     |      |    |      |  | Hyos des |
| <i>Hyoscyamus muticus</i>      |    |      | 49.98 | 3.33 |      |      |      |       |       |     |      |    |      |  | Hyos mut |
| <i>Imperata cylindrica</i>     |    |      |       |      |      |      |      |       |       |     |      | 50 | 4.00 |  | Impe cyl |
| <i>Iphiaea mucronata</i>       | 25 | 3.00 |       |      |      |      |      |       |       |     |      |    |      |  | Iphi muc |
| <i>Ipomoea pes-caprae</i>      |    |      | 16.6  | 1.00 |      |      |      |       |       |     |      |    |      |  | Ipom pes |
| <i>Juncus rigidus</i>          |    |      |       |      |      |      |      | 14.28 | 4.00  |     |      |    |      |  | Junu rig |
| <i>Lasiurus scindicus</i>      |    |      | 49.81 | 2.5  | 33.3 | 2.00 |      |       |       |     |      |    |      |  | Lasi sci |
| <i>Launaea nudicaulis</i>      |    |      | 16.6  | 2.00 |      |      |      |       |       |     |      |    |      |  | Laun muc |
| <i>Launaea spinosa</i>         | 25 | 3.00 |       |      |      |      |      |       |       |     |      |    |      |  | Laun pro |
| <i>Launaea mucronata</i>       |    |      |       |      |      |      |      | 14.28 | 1.0   |     |      | 25 | 2.00 |  | Laun spi |
| <i>Lepidium didymum</i>        |    |      |       |      |      |      |      |       |       | 25  | 2.00 |    |      |  | Lepi did |
| <i>Leptadenia pyrotechnica</i> | 25 | 3.00 | 49.8  | 2.3  | 33.3 | 2.00 | 25   | 1.00  | 28.56 | 3.0 |      |    |      |  | Lept pyr |
| <i>Limonium pruinatum</i>      |    |      |       |      |      |      |      |       |       |     |      | 50 | 2.00 |  | Limo pru |
| <i>Lycium shawii</i>           | 50 | 3.00 |       |      |      |      |      |       |       |     |      |    |      |  | Lyci sha |
| <i>Lysimachia arvensis</i>     |    |      |       |      |      |      |      |       |       | 25  | 2.00 |    |      |  | Lysi arv |
| <i>Malva parviflora</i>        |    |      |       |      |      |      |      |       |       | 25  | 3.00 |    |      |  | Malv par |
| <i>Melilotus indicus</i>       |    |      |       |      |      |      |      |       |       |     |      | 50 | 4.00 |  | Meli ind |
| <i>Nitraria retusa</i>         |    |      |       |      |      |      | 33.3 | 3.00  | 57.12 | 2.0 |      |    |      |  | Nitr ret |
| <i>Ochradenus baccatus</i>     | 75 | 2.6  | 83.3  | 3.00 | 100  | 2.66 | 50   | 1.5   | 14.28 | 1.0 |      | 50 | 3.00 |  | Ochr bac |
| <i>Panicum turgidum</i>        |    |      | 16.6  | 1.00 | 33.3 | 2.00 |      |       |       |     |      |    |      |  | Pani tur |

|                              |           |             |             |             |             |             |           |             |              |             |            |             |            |             |                 |
|------------------------------|-----------|-------------|-------------|-------------|-------------|-------------|-----------|-------------|--------------|-------------|------------|-------------|------------|-------------|-----------------|
| <i>Pergularia tomentosa</i>  |           |             | <b>16.6</b> | <b>3.00</b> |             |             |           |             |              |             |            |             |            |             | <b>Perg tom</b> |
| <i>Phoenix dactylifera</i>   |           |             |             |             |             |             |           |             | <b>14.28</b> | <b>2.00</b> |            |             |            |             | <b>Phoe dac</b> |
| <i>Phragmites australis</i>  | <b>25</b> | <b>2.00</b> |             |             |             |             |           |             | <b>71.42</b> | <b>3.00</b> | <b>75</b>  | <b>3.33</b> | <b>50</b>  | <b>3.00</b> | <b>Phra aus</b> |
| <i>Plantago ovata</i>        |           |             | <b>16.6</b> | <b>1.00</b> |             |             |           |             |              |             |            |             |            |             | <b>Plat ova</b> |
| <i>Pluchea dioscoridis</i>   |           |             |             |             |             |             | <b>25</b> | <b>2.00</b> |              |             |            |             | <b>50</b>  | <b>2.00</b> | <b>Pluc dio</b> |
| <i>Portulaca oleracea</i>    |           |             |             |             |             |             |           |             |              |             | <b>50</b>  | <b>2.00</b> |            |             | <b>Port ole</b> |
| <i>Pulicaria incisa</i>      |           |             |             |             |             |             | <b>25</b> | <b>2.00</b> |              |             |            |             | <b>50</b>  | <b>2.00</b> | <b>Puli inc</b> |
| <i>Pulicaria undulata</i>    |           |             |             |             |             |             |           |             | <b>14.28</b> | <b>2.00</b> |            |             |            |             | <b>Puli und</b> |
| <i>Reichardia tingitana</i>  |           |             |             |             |             |             | <b>25</b> | <b>2.00</b> |              |             |            |             |            |             | <b>Reic tin</b> |
| <i>Reseda pruinosa</i>       |           |             |             |             |             |             | <b>25</b> | <b>2.00</b> |              |             |            |             |            |             | <b>Rese pru</b> |
| <i>Rumex spinosus</i>        |           |             |             |             |             |             |           |             |              |             |            |             | <b>25</b>  | <b>2.00</b> | <b>Rume spi</b> |
| <i>Rumex vesicarius</i>      |           |             |             |             |             |             | <b>25</b> | <b>2.00</b> |              |             |            |             | <b>50</b>  | <b>3.00</b> | <b>Rume ves</b> |
| <i>Senecio glaucus</i>       |           |             |             |             |             |             |           |             |              |             |            |             | <b>50</b>  | <b>1.00</b> | <b>Sene gla</b> |
| <i>Solanum lycopersicum</i>  |           |             |             |             |             |             |           |             |              |             | <b>25</b>  | <b>3.00</b> |            |             | <b>Sola lyc</b> |
| <i>Solanum nigrum</i>        |           |             |             |             |             |             |           |             |              |             | <b>25</b>  | <b>2.00</b> |            |             | <b>Sola nig</b> |
| <i>Sonchus oleraceus</i>     |           |             |             |             |             |             |           |             |              |             | <b>50</b>  | <b>2.00</b> | <b>50</b>  | <b>2.00</b> | <b>Sonc ole</b> |
| <i>Tamarix aphylla</i>       | <b>25</b> | <b>4.00</b> |             |             |             |             |           |             | <b>14.28</b> | <b>2.0</b>  |            |             | <b>100</b> | <b>2.00</b> | <b>Tam aph</b>  |
| <i>Tamarix nilotica</i>      |           |             | <b>33.2</b> | <b>2.5</b>  | <b>66.6</b> | <b>3.5</b>  | <b>75</b> | <b>3.00</b> | <b>100</b>   | <b>3.28</b> | <b>100</b> | <b>4.00</b> | <b>50</b>  | <b>1.00</b> | <b>Tam nil</b>  |
| <i>Tamarix tetragyna</i>     |           |             |             |             |             |             |           |             |              |             | <b>75</b>  | <b>2.00</b> |            |             | <b>Tam tet</b>  |
| <i>Taverniera aegyptiaca</i> |           |             | <b>16.6</b> | <b>1.00</b> | <b>33.3</b> | <b>2.00</b> |           |             | <b>14.28</b> | <b>2.0</b>  |            |             |            |             | <b>Tave aeg</b> |
| <i>Traganum nudatum</i>      | <b>25</b> | <b>4.00</b> |             |             |             |             |           |             | <b>14.28</b> | <b>1.0</b>  |            |             | <b>50</b>  | <b>1.00</b> | <b>Trag nud</b> |
| <i>Tribulus mollis</i>       |           |             | <b>16.6</b> | <b>2.00</b> |             |             |           |             |              |             |            |             |            |             | <b>Trib mol</b> |

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|   |           |             |             |             |             |             |            |             |              |             |           |             |           |             |                  |
|---|-----------|-------------|-------------|-------------|-------------|-------------|------------|-------------|--------------|-------------|-----------|-------------|-----------|-------------|------------------|
| <i>Tribulus terrestris</i>                |           |             |             |             |             |             | <b>25</b>  | <b>1.00</b> |              |             |           |             |           |             | <b>Trib ter</b>  |
| <i>Trichodesma africanum</i>              |           |             | <b>16.4</b> | <b>2.00</b> |             |             | <b>100</b> | <b>3.00</b> |              |             |           |             |           |             | <b>Tric afr</b>  |
| <i>Urospermum picroides</i>               |           |             |             |             |             |             |            |             |              |             | <b>25</b> | <b>1.00</b> |           |             | <b>Uros pic</b>  |
| <i>Vachellia tortilis subsp. raddiana</i> | <b>25</b> | <b>1.00</b> | <b>16.6</b> | <b>1.00</b> | <b>33.3</b> | <b>1.00</b> |            |             |              |             |           |             |           |             | <b>Vac t rad</b> |
| <i>Zilla spinosa</i>                      | <b>25</b> | <b>4.00</b> | <b>83.3</b> | <b>3.8</b>  | <b>66.6</b> | <b>3.00</b> | <b>25</b>  | <b>3.00</b> | <b>14.28</b> | <b>2.0</b>  | <b>25</b> | <b>2.00</b> | <b>50</b> | <b>2.00</b> | <b>Zill spi</b>  |
| <i>Zygophyllum coccineum</i>              | <b>50</b> | <b>2.00</b> | <b>100</b>  | <b>3.16</b> | <b>100</b>  | <b>3.66</b> | <b>100</b> | <b>4.00</b> | <b>42.84</b> | <b>3.0</b>  | <b>75</b> | <b>3.66</b> |           |             | <b>Zyg ara</b>   |
| <i>Zygophyllum arabicum</i>               |           |             | <b>16.6</b> | <b>1.00</b> |             |             | <b>25</b>  | <b>3.00</b> | <b>28.54</b> | <b>2.00</b> |           |             |           |             | <b>Zyg coc</b>   |
| <i>Zygophyllum bruguieri</i>              |           |             |             |             | <b>33.3</b> | <b>2.00</b> |            |             |              |             |           |             |           |             | <b>Zyg bru</b>   |
| <i>Zygophyllum album</i>                  |           |             |             |             |             |             |            |             |              |             | <b>25</b> | <b>2.00</b> |           |             | <b>Zyg alb</b>   |
| <i>Zygophyllum decumbens</i>              | <b>25</b> | <b>2.00</b> |             |             |             |             |            |             |              |             |           |             |           |             | <b>Zyg dec</b>   |
| <i>Zygophyllum molle</i>                  | <b>25</b> | <b>1.00</b> |             |             |             |             |            |             | <b>14.28</b> | <b>2.0</b>  |           |             |           |             | <b>Zyg mol</b>   |
| <i>Zygophyllum simplex</i>                | <b>25</b> | <b>1.00</b> |             |             | <b>33.3</b> | <b>2.00</b> | <b>25</b>  | <b>2.00</b> | <b>14.28</b> | <b>2.0</b>  |           |             |           |             | <b>Zyg Sim</b>   |

TWINSPAN analysis categorized the inland collection sites into five distinct assemblages: *Tamarix nilotica* assemblage, *Zilla spinosa* assemblage, *Launaea spinosa* assemblage, *Zygophyllum coccineum*–*Farsetia aegyptia* assemblage, and a complex assemblage including *Anabasis articulata*, *Anastatica hierochuntica*, *Matthiola longipetala*, *Gymnocarpos decander*, *Lycium shawii*, *Melilotus indicus*, *Imperata cylindrica*, and *Zygophyllum mole*. The species composition and their percentages of presence within these assemblages are presented in Table (3). The first assemblage was dominated by *Tamarix nilotica*, with a 75% presence and an average abundance of 2.00. Codominant species included *Traganum nudatum*, *Convolvulus lanatus*, *Zilla spinosa*, *Haloxylon salicornicum*, and *Rumex vesicarius*, each with 50% presence and average abundances of 2.00 and 1.00. The second assemblage was characterized by *Zilla spinosa* as the dominant species, with 100% presence and an average abundance of 2.76. Codominant species were *Ochradenus baccatus* (92.28%, 3.00) and *Zygophyllum coccineum* (84.59%, 2.90), while associated species included *Haloxylon salicornicum* (53.13%, 1.85) and *Tamarix nilotica* (46.14%, 2.50). In the third assemblage, *Launaea spinosa* was the dominant species, with 87.5% presence and an average abundance of 2.71. Codominant species included *Zygophyllum decumbens*, *Iphiona mucronata*, and *Zilla spinosa*, each with 75% presence and average abundances of 1.83, 2.50, and 2.60, respectively. The associated species *Ochradenus baccatus* exhibited 62.5% presence and an average abundance of 2.20. The fourth assemblage was dominated by *Farsetia aegyptia* and *Zygophyllum coccineum*, both with 100% presence and average abundances of 3.75. Codominant species included *Haloxylon salicornicum*, *Anabasis setifera*, *Lycium shawii*, and *Tamarix tetragyna*, each with 75% presence and average abundances of 3.00, 3.60, 2.30, and 1.33, respectively. Associated species such as *Zygophyllum mole*, *Ochradenus baccatus*, *Vachellia tortilis subsp. raddiana*, *Portulaca oleracea*, and *Sonchus oleraceus* exhibited 50% presence and average abundances ranging from 2.00 to 2.50. The fifth assemblage was dominated by a diverse group of species including *Zygophyllum simplex*, *Anabasis articulata*, *Anastatica hierochuntica*, *Matthiola longipetala*, *Gymnocarpos decander*, *Lycium shawii*, *Zygophyllum mole*, *Melilotus indicus*, and *Imperata cylindrica*, all with 100% presence and average abundances of 1.00 to 4.00.

This study analyzed sixteen physical and chemical environmental factors, which were categorized into two main groups. The first group encompassed the physical characteristics of soil, including soil texture (determined by the pipette method), soil moisture content, organic carbon, and organic matter content. The second group focused on the chemical properties of soil, including acidity (pH), electrical conductivity (EC), cations, anions, and total carbonate, expressed as a percentage of weight. The ranges and mean values of these environmental variables across the sites corresponding to each

## Floristic Composition and Edaphic Influences in the Gulf of Suez

assemblage provide insight into the extent of variation within the coastline areas of the study area. Notable differences were observed among the physical and chemical attributes of the seven assemblages (Table 4). The second assemblage exhibited the highest percentages of sand (98.1%), silt (30.5%), calcium carbonate ( $\text{CaCO}_3$ , 26%) and pH (8.61). In contrast, assemblage seven recorded the highest values for clay content (28.2%), electrical conductivity (1410 dS/m), potassium (18.7 mEq/L), and soil moisture content (12.1%). Assemblage five displayed the maximum concentrations of sodium ( $\text{Na}^+$ , 858 mEq/L), magnesium ( $\text{Mg}^{2+}$ , 180 mEq/L), calcium ( $\text{Ca}^{2+}$ , 470 mEq/L), chloride ( $\text{Cl}^-$ , 1196 mEq/L), and bicarbonate ( $\text{HCO}_3^-$ , 81 mEq/L). Meanwhile, the highest levels of sulfate ( $\text{SO}_4^{2-}$ , 329 mEq/L) were observed in assemblage six. Significant differences were observed among the physical and chemical attributes of the five assemblages associated with plant species collected from the inland areas (Table 5). The third assemblage showed the highest percentages of sand (92.5%), organic matter (0.7%), organic carbon (0.43%), and magnesium ( $\text{Mg}^{2+}$ , 20.8 mEq/L). Conversely, assemblage two recorded the maximum values for soil moisture content (11.5%), potassium ( $\text{K}^+$ , 0.4 mEq/L), sodium ( $\text{Na}^+$ , 58.4 mEq/L), calcium ( $\text{Ca}^{2+}$ , 40 mEq/L), chloride ( $\text{Cl}^-$ , 41.8 mEq/L), sulfate ( $\text{SO}_4^{2-}$ , 34.3 mEq/L), and calcium carbonate ( $\text{CaCO}_3$ , 34.3%). Meanwhile, the fourth assemblage exhibited the highest levels of clay (84.8%), pH (9.24), electrical conductivity (EC, 7.66 dS/m), and bicarbonate ( $\text{HCO}_3^-$ , 18 mEq/L).

The Canonical Correspondence Analysis (CCA) ordination classified the 93 plant species collected from the coastline sites into four distinct sections (Figure 4). The first section (I) comprised species positively influenced by electrical conductivity (EC), sodium ( $\text{Na}^+$ ), magnesium ( $\text{Mg}^{2+}$ ), potassium ( $\text{K}^+$ ), calcium ( $\text{Ca}^{2+}$ ), chloride ( $\text{Cl}^-$ ), bicarbonate ( $\text{HCO}_3^-$ ), sulfate ( $\text{SO}_4^{2-}$ ), and silt. This group included *Bassia eriophora*, *Halopeplis perfoliata*, *Reichardia tingitana*, *Limonium pruinatum*, *Phragmites australis*, *Tamarix nilotica*, *Zygophyllum coccineum*, and *Zygophyllum simplex*. But, the third section (III) was represented by species such as *Cleome amplyocarpa*, *Achillea fragrantissima*, *Cucumis melo*, *Plantago ovata*, and *Tribulus mollis*, which were negatively influenced by the same mentioned factors. The fourth section (IV) included species such as *Chenopodium album*, *Sonchus oleraceus*, *Melilotus indicus*, and *Malva parviflora*, which were positively associated with soil moisture. Conversely, the second section (II) comprised species such as *Zygophyllum album*, *Haloxylon salicornicum* and *Convolvulus lanatus* which were negatively affected by soil moisture.

**Table 3.** Phytosociological table showing presence percentage and average abundance for inland sites main assemblages resulted from TWINSpan classification. Avg=Average abundance; P =Presence

| Group                           | I  |      | II    |      | III  |      | IV |      | V   |      | Species Abbreviations |
|---------------------------------|----|------|-------|------|------|------|----|------|-----|------|-----------------------|
|                                 | 4  |      | 13    |      | 8    |      | 4  |      | 1   |      |                       |
|                                 | P  | Avg  | P     | Avg  | P    | Avg  | P  | Avg  | P   | Avg  |                       |
| <i>Achillea fragrantissima</i>  |    |      | 15.38 | 1.5  | 12.5 | 1.00 |    |      |     |      | Achi fra              |
| <i>Anabasis articulata</i>      |    |      |       |      |      |      |    |      | 100 | 2.00 | Anab art              |
| <i>Anabasis setifera</i>        |    |      |       |      |      |      | 75 | 3.6  |     |      | Anab seti             |
| <i>Anastatica hierochuntica</i> |    |      |       |      | 37.5 | 1.5  |    |      | 100 | 2.00 | Anas hie              |
| <i>Artemisia judaica</i>        |    |      | 7.69  | 1.00 |      |      |    |      |     |      | Arte jud              |
| <i>Astragalus sieberi</i>       |    |      |       |      | 12.5 | 2.00 |    |      |     |      | Astr sie              |
| <i>Atriplex humilis</i>         | 25 | 1.00 |       |      |      |      |    |      |     |      | Atri hum              |
| <i>Bassia eriophora</i>         |    |      |       |      | 12.5 | 2.00 |    |      |     |      | Bass eri              |
| <i>Brocchia cinerea</i>         |    |      |       |      | 12.5 | 2.00 |    |      |     |      | Broc cin              |
| <i>Caylusea hexagyna</i>        |    |      |       |      |      |      | 25 | 3.00 |     |      | Cayl hex              |
| <i>Centaurea aegyptiaca</i>     | 25 | 2.00 |       |      |      |      |    |      |     |      | Cent aeg              |
| <i>Cistanche tubulosa</i>       |    |      |       |      | 12.5 | 2.00 |    |      |     |      | Cist tub              |

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|                                  |    |      |       |      |      |      |     |      |     |      |          |
|----------------------------------|----|------|-------|------|------|------|-----|------|-----|------|----------|
| <i>Citrullus colocynthis</i>     | 25 | 3.00 |       |      |      |      |     |      |     |      | Citr col |
| <i>Cleome amblyocarpa</i>        | 25 | 2.00 |       |      |      |      |     |      |     |      | Cleo amb |
| <i>Cleome droserifolia</i>       |    |      |       |      | 12.5 | 2.00 |     |      |     |      | Cleo dro |
| <i>Convolvulus lanatus</i>       | 50 | 2.00 |       |      |      |      |     |      |     |      | Conv lan |
| <i>Crotalaria aegyptiaca</i>     |    |      | 30.76 | 2.25 | 25   | 2.5  |     |      |     |      | Crot aeg |
| <i>Deverra tortuosa</i>          |    |      | 15.38 | 2.00 | 12.5 | 4.00 |     |      |     |      | Deve tor |
| <i>Diplotaxis acris</i>          | 25 | 2.00 |       |      |      |      |     |      |     |      | Dipl fus |
| <i>Echinops spinosus</i>         |    |      | 15.38 | 2.5  | 37.5 | 2.6  | 25  | 3.00 |     |      | Echi spi |
| <i>Ephedra alata</i>             |    |      | 7.69  | 1.00 |      |      |     |      |     |      | Ephe ala |
| <i>Eremobium aegyptiacum</i>     |    |      |       |      |      |      | 25  | 2.00 |     |      | Erem aeg |
| <i>Euphorbia retusa</i>          | 25 | 2.00 |       |      |      |      |     |      |     |      | Euph ret |
| <i>Farsetia aegyptia</i>         |    |      | 7.69  | 2.00 | 12.5 | 2.00 | 100 | 3.25 |     |      | Fars aeg |
| <i>Gymnocarpos decander</i>      |    |      | 7.69  | 2.00 |      |      |     |      | 100 | 2.00 | Gymn dec |
| <i>Haloxylon persicum</i>        |    |      | 7.69  | 1.00 |      |      |     |      |     |      | Halo sal |
| <i>Haloxylon salicornicum</i>    | 50 | 2.00 | 53.73 | 1.85 |      |      | 75  | 3.00 |     |      | Halo sco |
| <i>Haplophyllum tuberculatum</i> |    |      | 7.69  | 2.00 |      |      |     |      |     |      | Hapl tub |
| <i>Heliotropium arbainense</i>   |    |      | 23.07 | 2.00 | 37.5 | 3.00 |     |      |     |      | Heli arb |



|                                 |           |             |              |             |             |             |           |             |            |             |                   |
|---------------------------------|-----------|-------------|--------------|-------------|-------------|-------------|-----------|-------------|------------|-------------|-------------------|
| <i>Heliotropium digyllum</i>    |           |             |              |             | <b>12.5</b> | <b>2.00</b> |           |             |            |             | <b>Heli dig</b>   |
| <i>Hyoscyamus boveanus</i>      | <b>25</b> | <b>2.00</b> |              |             |             |             |           |             |            |             | <b>Hyos bov</b>   |
| <i>Ifloga spicata</i>           |           |             |              |             | <b>12.5</b> | <b>2.00</b> |           |             |            |             | <b>Iflo spi</b>   |
| <i>Imperata cylindrica</i>      |           |             |              |             |             |             | <b>25</b> | <b>2.00</b> |            |             | <b>Impe cyl</b>   |
| <i>Iphiona mucronata</i>        |           |             | <b>46.14</b> | <b>3.6</b>  | <b>75</b>   | <b>2.5</b>  |           |             |            |             | <b>Iphi muc</b>   |
| <i>Kickxia aegyptiaca</i>       |           |             | <b>7.69</b>  | <b>1.00</b> |             |             | <b>25</b> | <b>2.00</b> |            |             | <b>Kick aeg</b>   |
| <i>Launaea nudicaulis</i>       |           |             | <b>7.69</b>  | <b>2.00</b> | <b>12.5</b> | <b>1.00</b> |           |             |            |             | <b>Laun muc</b>   |
| <i>Launaea procumbens</i>       | <b>25</b> | <b>2.00</b> |              |             |             |             |           |             |            |             | <b>Laun nud</b>   |
| <i>Launaea spinosa</i>          |           |             | <b>15.38</b> | <b>2.00</b> | <b>87.5</b> | <b>2.71</b> |           |             |            |             | <b>Laun pro</b>   |
| <i>Launaea mucronata</i>        | <b>25</b> | <b>2.00</b> |              |             |             |             |           |             |            |             | <b>Laun spi</b>   |
| <i>Lavandula coronopifolia.</i> |           |             | <b>7.69</b>  | <b>1.00</b> | <b>37.5</b> | <b>2.00</b> |           |             |            |             | <b>Lava cor</b>   |
| <i>Leptadenia pyrotechnica</i>  |           |             |              |             |             |             |           |             | <b>25</b>  | <b>3.00</b> | <b>Lept pyr</b>   |
| <i>Limonium pruinosum</i>       |           |             |              |             |             |             |           |             |            |             | <b>Limo pru</b>   |
| <i>Lycium shawii</i>            |           |             | <b>23.07</b> | <b>1.66</b> | <b>25</b>   | <b>2.00</b> | <b>75</b> | <b>2.3</b>  | <b>100</b> | <b>2.00</b> | <b>Lyci sha</b>   |
| <i>Matthiola longipetala</i>    |           |             |              |             |             |             |           |             | <b>100</b> | <b>2.00</b> | <b>Matt l bi</b>  |
| <i>Matthiola longipetala</i>    |           |             |              |             |             |             |           |             | <b>100</b> | <b>2.00</b> | <b>Matt l liv</b> |
| <i>Nidorella aegyptiaca</i>     |           |             |              |             | <b>12.5</b> | <b>2.00</b> |           |             |            |             | <b>Nido aeg</b>   |

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|                               |    |      |       |      |      |      |    |      |     |      |  |          |
|-------------------------------|----|------|-------|------|------|------|----|------|-----|------|--|----------|
| <i>Nitraria retusa</i>        |    |      |       |      | 12.5 | 2.00 |    |      |     |      |  | Nitr ret |
| <i>Ochradenus baccatus</i>    | 25 | 2.00 | 92.28 | 3.00 | 62.5 | 2.2  | 50 | 2.5  |     |      |  | Ochr bac |
| <i>Panicum turgidum</i>       |    |      | 13.07 | 2.3  | 25   | 2.00 | 25 | 2.00 |     |      |  | Pani tur |
| <i>Pergularia tomentosa</i>   |    |      | 7.69  | 3.00 |      |      |    |      |     |      |  | Perg tom |
| <i>Phragmites australis</i>   |    |      | 15.38 | 2.5  | 25   | 3.00 | 25 | 2.00 |     |      |  | Phra aus |
| <i>Pluchea dioscoridis</i>    |    |      | 15.38 | 2.00 |      |      |    |      |     |      |  | Pluc dio |
| <i>Pulicaria incisa</i>       | 25 | 1.00 |       |      |      |      |    |      |     |      |  | Puli inc |
| <i>Pulicaria undulata</i>     |    |      | 30.76 | 1.75 |      |      |    |      |     |      |  | Puli und |
| <i>Retama raetam</i>          |    |      |       |      | 12.5 | 2.00 |    |      |     |      |  | Reta rae |
| <i>Rumex vesicarius</i>       | 50 | 1.00 |       |      | 37.5 | 1.5  |    |      | 100 | 1.00 |  | Rume ves |
| <i>Senecio glaucus</i>        | 25 | 2.00 |       |      |      |      |    |      |     |      |  | Sene gla |
| <i>Sonchus oleraceus</i>      |    |      |       |      | 12.5 | 1.00 |    |      |     |      |  | Sonc ole |
| <i>Tamarix nilotica</i>       | 75 | 2.00 | 46.14 | 2.5  | 12.5 | 2.00 |    |      |     |      |  | Tam nil  |
| <i>Tamarix tetragyna</i>      | 25 | 2.00 | 7.69  | 4.00 |      |      |    |      |     |      |  | Tam tet  |
| <i>Traganum nudatum</i>       | 50 | 2.00 |       |      |      |      |    |      |     |      |  | Trag nud |
| <i>Tribulus mollis</i>        |    |      |       |      | 12.5 | 1.00 |    |      |     |      |  | Trib mol |
| <i>Tricholaena teneriffae</i> |    |      |       |      |      |      |    |      | 100 | 2.00 |  | Tric ten |

|  |           |             |              |             |             |             |            |             |            |             |                  |
|--|-----------|-------------|--------------|-------------|-------------|-------------|------------|-------------|------------|-------------|------------------|
| <i>Vachellia tortilis</i> subsp. <i>raddiana</i> |           |             | <b>15.38</b> | <b>2.5</b>  | <b>25</b>   | <b>1.00</b> | <b>50</b>  | <b>2.00</b> |            |             | <b>Vac t rad</b> |
| <i>Vachellia tortilis</i> subsp. <i>tortilis</i> |           |             | <b>7.69</b>  | <b>2.00</b> |             |             |            |             |            |             | <b>Vac t tor</b> |
| <i>Zilla spinosa</i>                             | <b>50</b> | <b>2.00</b> | <b>100</b>   | <b>2.76</b> | <b>75</b>   | <b>2.6</b>  | <b>25</b>  | <b>3.00</b> |            |             | <b>Zill spi</b>  |
| <i>Zygophyllum coccineum</i>                     | <b>25</b> | <b>2.00</b> | <b>84.59</b> | <b>2.9</b>  |             |             | <b>100</b> | <b>3.75</b> | <b>100</b> | <b>2.00</b> | <b>Zyg ara</b>   |
| <i>Zygophyllum arabicum</i>                      | <b>25</b> | <b>2.00</b> | <b>30.76</b> | <b>1.5</b>  |             |             |            |             |            |             | <b>Zyg coc</b>   |
| <i>Zygophyllum bruguieri</i>                     |           |             | <b>7.69</b>  | <b>2.00</b> |             |             | <b>25</b>  | <b>1.00</b> |            |             | <b>Zyg bru</b>   |
| <i>Zygophyllum album</i>                         |           |             |              |             | <b>12.5</b> | <b>2.00</b> |            |             |            |             | <b>Zyg alb</b>   |
| <i>Zygophyllum decumbens</i>                     | <b>25</b> | <b>2.00</b> | <b>15.38</b> | <b>2.00</b> | <b>75</b>   | <b>1.83</b> |            |             |            |             | <b>Zyg dec</b>   |
| <i>Zygophyllum molle</i>                         | <b>25</b> | <b>2.00</b> | <b>7.69</b>  | <b>1.00</b> |             |             | <b>50</b>  | <b>2.5</b>  | <b>100</b> | <b>2.00</b> | <b>Zyg mol</b>   |
| <i>Zygophyllum simplex</i>                       |           |             |              |             |             |             |            |             | <b>100</b> | <b>1.00</b> | <b>Zyg Sim</b>   |

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**Table 4.** Minimum, maximum, mean, and standard deviation of environmental variables for the main assemblages of coastline plants resulted from TWINSPAN

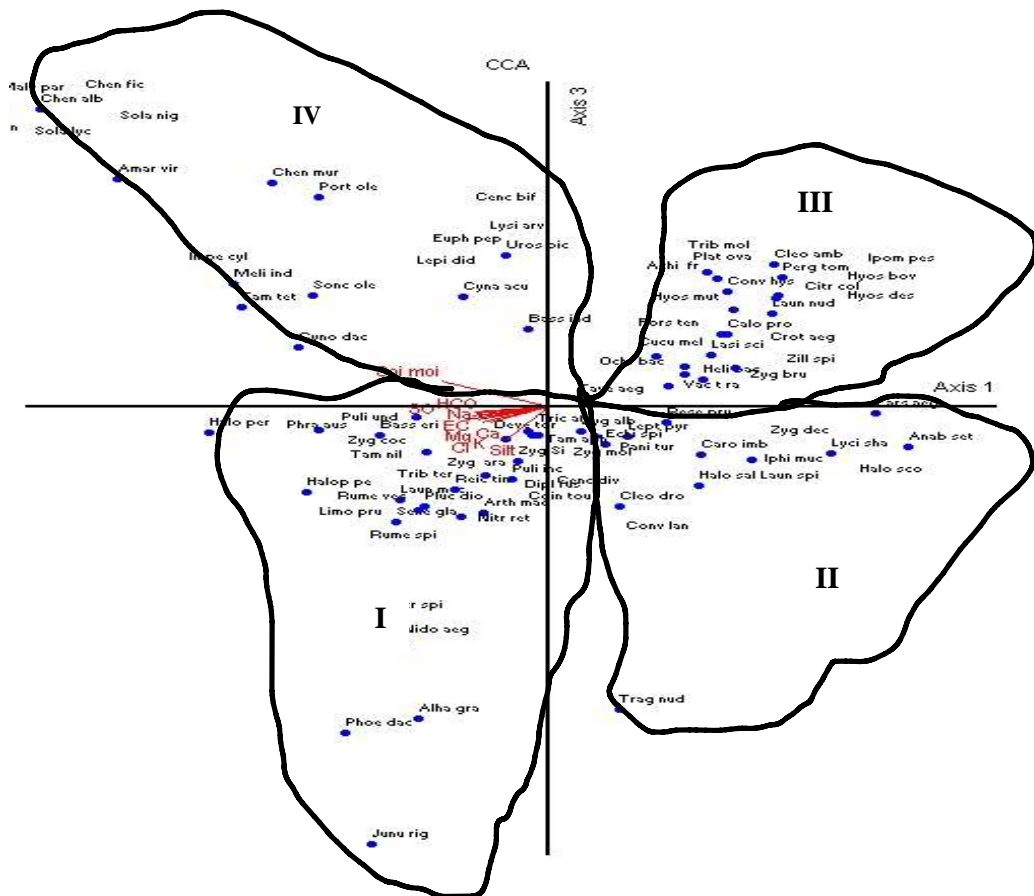
| Assemblage                    | I                   |      |       |         | II   |      |       |         | III  |      |       |         | IV   |      |        |         | V    |      |       |         | VI   |      |       |         | VII  |      |       |         |
|-------------------------------|---------------------|------|-------|---------|------|------|-------|---------|------|------|-------|---------|------|------|--------|---------|------|------|-------|---------|------|------|-------|---------|------|------|-------|---------|
|                               | 4                   |      |       |         | 6    |      |       |         | 3    |      |       |         | 4    |      |        |         | 7    |      |       |         | 4    |      |       |         | 2    |      |       |         |
| No. of sites                  | Min                 | Max  | Mean  | Std Dev | Min  | Max  | Mean  | Std Dev | Min  | Max  | Mean  | Std Dev | Min  | Max  | Mean   | Std Dev | Min  | Max  | Mean  | Std Dev | Min  | Max  | Mean  | Std Dev | Min  | Max  | Mean  | Std Dev |
| Soil texture (pipette)        | Physical properties |      |       |         |      |      |       |         |      |      |       |         |      |      |        |         |      |      |       |         |      |      |       |         |      |      |       |         |
| Sand%                         | 47.6                | 80   | 54.17 | 5.32    | 54   | 89.1 | 72.46 | 12.49   | 61   | 69.8 | 65    | 4.44    | 37.5 | 66.8 | 48     | 13.8    | 96.3 | 80.5 | 71.61 | 8.41    | 61.2 | 82.9 | 73.52 | 9       | 56.4 | 70   | 63.2  | 9.61    |
| Silt%                         | 4.7                 | 23   | 14.48 | 9.92    | 4.3  | 30.5 | 16.71 | 9.98    | 7    | 12.1 | 8.73  | 2.91    | 7.5  | 22.5 | 12.97  | 6.55    | 7.3  | 21.6 | 14.47 | 4.8     | 9.3  | 18.4 | 11.8  | 4.4     | 15.4 | 20   | 17.7  | 3.2     |
| Clay%                         | 9.7                 | 20.5 | 15    | 4.08    | 6.8  | 15.5 | 8.73  | 3.64    | 9.8  | 11.9 | 11.1  | 1.13    | 12.5 | 22.2 | 17.15  | 4.27    | 3.1  | 17.8 | 10.8  | 5       | 7.3  | 20.4 | 14.67 | 5.47    | 10   | 28.2 | 19.1  | 12.86   |
| Organic matter%               | 0.22                | 0.51 | 0.36  | 0.16    | 0.05 | 0.49 | 0.24  | 0.19    | 0.39 | 1.11 | 0.667 | 0.38    | 0.42 | 1.11 | 0.75   | 0.29    | 0.65 | 1.18 | 0.31  | 0.40    | 0.10 | 0.42 | 0.32  | 0.14    | 13   | 12.5 | 0.31  | 0.16    |
| Organic carbon %              | 0.13                | 0.30 | 0.21  | 0.094   | 0.03 | 0.2  | 0.14  | 0.11    | 0.22 | 0.64 | 0.38  | 0.22    | 0.24 | 0.64 | 0.43   | 0.17    | 0.63 | 0.68 | 0.18  | 0.23    | 0.06 | 0.24 | 0.18  | 0.08    | 0.19 | 0.42 | 0.18  | 0.09    |
| Moisture content %            | 0.39                | 2.2  | 1.23  | 0.82    | 0.6  | 1.7  | 1.08  | 0.47    | 0.7  | 0.99 | 0.83  | 0.14    | 2.3  | 6    | 3.69   | 1.73    | 0.7  | 7.7  | 2.85  | 2.37    | 2.5  | 11.9 | 4.09  | 4.07    | 3.9  | 12.1 | 8     | 5.7     |
| Chemical properties           |                     |      |       |         |      |      |       |         |      |      |       |         |      |      |        |         |      |      |       |         |      |      |       |         |      |      |       |         |
| pH                            | 8.14                | 8.97 | 8.61  | 0.35    | 7.57 | 8.61 | 8.1   | 0.37    | 7.57 | 7.82 | 7.66  | 0.13    | 7.13 | 8.12 | 7.52   | 0.45    | 7.11 | 8.42 | 7.91  | 0.45    | 7.65 | 8.47 | 8.1   | 0.34    | 6.8  | 8.49 | 7.68  | 1.14    |
| EC (ds/m)                     | 1.3                 | 18.7 | 10.32 | 7.11    | 1.06 | 13.4 | 5.08  | 4.5     | 10.5 | 43.2 | 23.63 | 17.72   | 12.5 | 76.2 | 46.3   | 34.0    | 4.87 | 151  | 53    | 55.69   | 8.14 | 11.1 | 40.8  | 23.9    | 83   | 1410 | 94.2  | 122.6   |
| Cations (mEq/L)               |                     |      |       |         |      |      |       |         |      |      |       |         |      |      |        |         |      |      |       |         |      |      |       |         |      |      |       |         |
| Ca <sup>2+</sup>              | 7                   | 86   | 43.8  | 33.1    | 2.8  | 87   | 21.76 | 19.28   | 96   | 181  | 94.33 | 90      | 26.7 | 240  | 139.3  | 111.4   | 26.4 | 470  | 126.3 | 198.6   | 18.3 | 178  | 72    | 72.9    | 18.9 | 335  | 110.5 | 106.7   |
| Mg <sup>2+</sup>              | 5.6                 | 24   | 17.62 | 8.28    | 2.1  | 24   | 11.5  | 8.13    | 27   | 99   | 51.33 | 41.28   | 20   | 150  | 89     | 45.6    | 16.2 | 180  | 64.4  | 60.8    | 14.5 | 119  | 83.37 | 45.7    | 0.19 | 0.42 | 70    | 77.7    |
| Na <sup>+</sup>               | 3.2                 | 78.4 | 42.12 | 32.4    | 4.4  | 52.5 | 17.7  | 29.3    | 20.7 | 181  | 90    | 82.3    | 77.9 | 378  | 233.4  | 182.7   | 5.8  | 858  | 338.4 | 35.8    | 51.3 | 811  | 281.9 | 356.1   | 0.11 | 0.24 | 760   | 1040    |
| K <sup>+</sup>                | 0.2                 | 0.6  | 0.42  | 0.17    | 0.2  | 0.5  | 0.31  | 0.11    | 0.3  | 1    | 0.63  | 0.35    | 0.4  | 1    | 1.2    | 0.92    | 0.3  | 2    | 1.12  | 0.81    | 0.3  | 2    | 0.8   | 0.80    | 10.2 | 18.7 | 1.7   | 1.83    |
| Anions (mEq/L)                |                     |      |       |         |      |      |       |         |      |      |       |         |      |      |        |         |      |      |       |         |      |      |       |         |      |      |       |         |
| HCO <sub>3</sub> <sup>-</sup> | 2.2                 | 10.8 | 6.95  | 3.78    | 1.6  | 7.9  | 3.91  | 2.23    | 2.6  | 45   | 9.86  | 22.26   | 8.6  | 71   | 36.45  | 36.46   | 4    | 81   | 24.9  | 27.8    | 11.2 | 54   | 25    | 19.62   | 6.87 | 8.49 | 34.3  | 43.4    |
| Cl <sup>-</sup>               | 6.2                 | 10.5 | 61.8  | 46.97   | 5.1  | 90   | 29    | 31.53   | 13   | 249  | 136   | 92.48   | 68.6 | 496  | 297.9  | 218.9   | 29   | 1196 | 373.0 | 427.9   | 34.9 | 727  | 250.9 | 321.5   | 7.55 | 181  | 731.5 | 959.5   |
| SO <sub>4</sub> <sup>2-</sup> | 4.0                 | 71.2 | 34.5  | 27.52   | 3.3  | 42.4 | 17.8  | 5.83    | 30   | 147  | 80.46 | 60.13   | 43.2 | 217  | 128.65 | 93.1    | 12   | 320  | 132.6 | 121.7   | 35.3 | 329  | 132   | 133.7   | 35   | 186  | 176.9 | 225.5   |
| CaCO <sub>3</sub> %           | 9.4                 | 23.7 | 16.85 | 7.59    | 9.3  | 26   | 19.8  | 6.08    | 7.5  | 23.7 | 18.2  | 9.26    | 18.2 | 24.5 | 21.45  | 2.87    | 8    | 24.6 | 14.32 | 7.14    | 20.8 | 24.9 | 22.87 | 1.7     | 0.4  | 3    | 14.35 | 6       |

**Table 5.** The minimum, maximum, mean, and standard deviation of environmental variables for the main assemblages of inland site plants resulted from TWINSpan

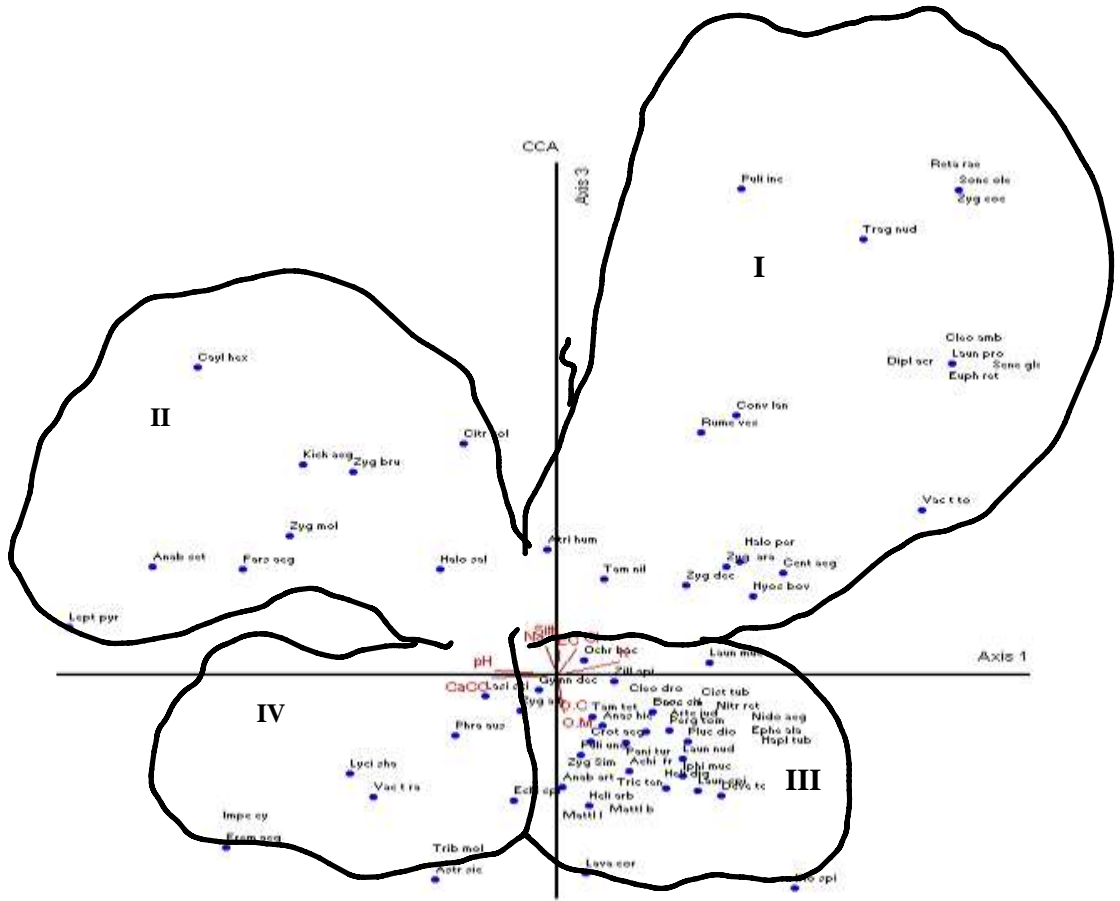
| Assemblage                    | I                   |      |       |         | II   |      |       |         | III  |      |       |         | IV   |      |       |         | V    |      |      |         |
|-------------------------------|---------------------|------|-------|---------|------|------|-------|---------|------|------|-------|---------|------|------|-------|---------|------|------|------|---------|
| No. of sites                  | 4                   |      |       |         | 13   |      |       |         | 8    |      |       |         | 4    |      |       |         | 1    |      |      |         |
| Soil texture (pipette)        | Min                 | Max  | Mean  | Std Dev | Min  | Max  | Mean  | Std Dev | Min  | Max  | Mean  | Std Dev | Min  | Max  | Mean  | Std Dev | Min  | Max  | Mean | Std Dev |
|                               | Physical properties |      |       |         |      |      |       |         |      |      |       |         |      |      |       |         |      |      |      |         |
| Sand%                         | 69                  | 73.8 | 71.67 | 2.05    | 59.5 | 87   | 72.19 | 9.1     | 50   | 92.5 | 70.96 | 13      | 8.7  | 23.4 | 13.3  | 6.91    | 69   | 69   | 69   | -       |
| Silt%                         | 16.7                | 92   | 14.15 | 3.3     | 32   | 64.1 | 11.2  | 7.5     | 2.2  | 23.7 | 9.7   | 7.79    | 6.5  | 12.8 | 8.57  | 2.9     | 13   | 13   | 13   | -       |
| Clay%                         | 6.7                 | 11.9 | 8.64  | 2.01    | 1    | 19.5 | 8.8   | 5.5     | 2.5  | 30   | 9.86  | 8.83    | 47.3 | 84.8 | 65.65 | 15.36   | 18   | 18   | 18   | -       |
| Organic matter%               | 0.05                | 0.17 | 0.13  | 0.05    | 0.05 | 0.66 | 0.29  | 0.19    | 0.05 | 0.7  | 0.35  | 0.22    | 0.14 | 0.61 | 0.33  | 0.20    | 0.05 | 0.05 | 0.05 | -       |
| Organic carbon %              | 0.10                | 0.03 | 0.07  | 0.03    | 0.03 | 0.38 | 0.17  | 0.10    | 0.03 | 0.43 | 0.20  | 0.13    | 0.08 | 0.35 | 0.19  | 0.12    | 0.03 | 0.03 | 0.03 | -       |
| Moisture content %            | 1.3                 | 2    | 1.5   | 0.35    | 0.2  | 11.5 | 2.49  | 2.92    | 0.44 | 5    | 2.09  | 1.72    | 0.26 | 1.32 | 0.87  | 0.44    | 1.2  | 1.2  | 1.2  | -       |
| Chemical properties           |                     |      |       |         |      |      |       |         |      |      |       |         |      |      |       |         |      |      |      |         |
| pH                            | 7.73                | 9.09 | 8.10  | 0.63    | 7.53 | 9.08 | 8.17  | 0.42    | 7.19 | 8.09 | 7.92  | 0.09    | 8.37 | 9.24 | 8.7   | 0.37    | 7.77 | 7.77 | 7.77 | -       |
| EC (ds/m)                     | 4.79                | 6.9  | 5.89  | 0.97    | 1.71 | 8.84 | 4.84  | 2.24    | 2.82 | 10.5 | 5.18  | 2.33    | 2.42 | 7.66 | 5     | 2.39    | 4.7  | 4.7  | 4.7  | -       |
| Cations ( mEq/L )             |                     |      |       |         |      |      |       |         |      |      |       |         |      |      |       |         |      |      |      |         |
| Ca <sup>2+</sup>              | 18.2                | 32   | 23.3  | 6.1     | 9.5  | 40   | 19.26 | 8.16    | 15   | 38   | 25.75 | 8       | 12.5 | 21   | 17.55 | 3.6     | 29.4 | 29.4 | 29.4 | -       |
| Mg <sup>2+</sup>              | 6                   | 15.1 | 12.3  | 4.29    | 4.4  | 16   | 11.32 | 3.78    | 4    | 20.8 | 12.45 | 4.87    | 11   | 15   | 12.47 | 1.7     | 13.6 | 13.6 | 13.6 | -       |
| Na <sup>+</sup>               | 9.5                 | 40.6 | 28.5  | 13.04   | 3.8  | 58.4 | 18.24 | 18      | 4.9  | 55.4 | 14.47 | 16.73   | 7.1  | 45.7 | 24.7  | 18.78   | 3.6  | 3.6  | 3.6  | -       |
| K <sup>+</sup>                | 0.3                 | 0.4  | 0.35  | 0.05    | 0.2  | 0.4  | 0.26  | 0.06    | 0.2  | 0.6  | 0.32  | 0.12    | 0.1  | 0.3  | 0.17  | 0.09    | 0.4  | 0.4  | 0.4  | -       |
| Anions ( mEq/L )              |                     |      |       |         |      |      |       |         |      |      |       |         |      |      |       |         |      |      |      |         |
| HCO <sub>3</sub> <sup>-</sup> | 4.4                 | 7.1  | 5.8   | 1.22    | 1.4  | 21   | 7.1   | 5.29    | 3    | 9.6  | 5.12  | 2.16    | 10.9 | 18   | 6.87  | 4.4     | 5    | 5    | 5    | -       |
| Cl <sup>-</sup>               | 27.2                | 39   | 32.6  | 5.6     | 7    | 41.8 | 24.21 | 10.65   | 15   | 65   | 29.7  | 15.4    | 12   | 36.1 | 25.22 | 10.29   | 26   | 26   | 26   | -       |
| SO <sub>4</sub> <sup>2-</sup> | 16.3                | 26.2 | 20.5  | 4.13    | 5.5  | 34.3 | 17.1  | 8.67    | 9    | 30.4 | 16.95 | 6.4     | 9.4  | 29.6 | 18.6  | 10.29   | 16   | 16   | 16   | -       |
| CaCO <sub>3</sub> %           | 6.5                 | 12   | 8.15  | 2.58    | 7.6  | 34.3 | 18.8  | 8.33    | 11.2 | 27.5 | 16    | 4.96    | 23.1 | 32.3 | 27.87 | 4.6     | 15.7 | 15.7 | 15.7 | -       |

## Floristic Composition and Edaphic Influences in the Gulf of Suez

The CCA ordination classified the 73 plant species collected from inland sites into four distinct sections (Figure 5). The first section (I) consisted of species positively influenced by electrical conductivity (EC), potassium (K<sup>+</sup>), chloride (Cl<sup>-</sup>), and silt. This group included *Tamarix nilotica*, *Zilla spinosa*, *Haloxylon persicum*, and *Convolvulus lanatus*. In contrast, the fourth section (IV) comprised species negatively affected by these same factors, such as *Vachellia tortilis* subsp. *raddiana*, *Lycium shawii*, *Imperata cylindrica*, and *Phragmites australis*. The second section (II) included species positively influenced by potassium (K<sup>+</sup>), pH, and calcium carbonate (CaCO<sub>3</sub>), such as *Kickxia aegyptiaca*, *Haloxylon salicornicum*, *Zygophyllum molle*, and *Caylusea hexagyna*. Finally, the third section (III) was represented by species positively associated with organic matter and organic carbon, including *Achillea fragrantissima*, *Ifloga spicata*, and *Anastatica hierochuntica*.



**Fig. 4.** Ordination diagram (CCA) with coastline plant species as points and selected environmental variables (physical and chemical)



**Fig. 5.** Ordination diagram (CCA) with coastline plant species as points and selected environmental variables (physical and chemical)

### Discussion

The studied sites represent the coastal and inland regions of the Eastern Desert, notable for their diverse wild plant species at both specific and generic levels. A total of 119 species were identified, distributed among 87 genera and 32 families. The Asteraceae family was the most diverse, representing (16.8%), followed by Amaranthaceae (13.4%), and then Zygophyllaceae. The prevalence of these families highlights the region's adaptation to extreme aridity and salinity. These conditions favor xerophytic plants with high salt tolerance, as noted by Aronson and Whitehead (1989). Additionally, Judd and Ferguson (1999) emphasized the adaptation of Amaranthaceae to semi-arid climates and saline habitats. The Zygophyllaceae family, in particular, is widely distributed in arid and semi-arid zones across both the Old and New Worlds, especially in seasonally dry desert environments (Abd El-Aal *et al.*, 2019).

The notable presence of Asteraceae, Amaranthaceae, Poaceae, Zygophyllaceae, Brassicaceae and Solanaceae in both inland and coastal sites highlighted their strong adaptation to saline habitats. However, the inland regions consistently exhibit a lower number of species within these families compared to the coastline. This pattern is likely due to the higher salinity levels found along the coastline, as shown in Table 4.

The families Juncaceae, Malvaceae, Plumbaginaceae, and Arecaceae were exclusively found along the coastline with no presence in the inland regions. This distinctive distribution underscores their strong adaptation to saline environments as these families are recognized for their exceptional salt tolerance as highlighted by Garcia-Caparros *et al.* (2023). Their restriction to the coastline further emphasizes the critical role of salinity in shaping their habitat preferences reflecting the unique conditions that coastal areas provide.

The life span distribution between inland and coastline areas shows notable differences. In the inland regions, 73 species were recorded, with 17 species (23.29%) being annuals and 54 species (73.97%) perennials. In contrast, the coastline, with 93 species, had a higher proportion of annuals, with 35 species (37.63%) compared to 58 species (62.37%) perennials. The higher proportion of annuals along the coastline can be linked to the increased rainfall and soil moisture in these sites, as shown in Table (4). However, it's important to highlight that both the inland and coastal regions are predominantly dominated by perennials. This suggests that, while the coastline experiences higher moisture levels, the overall rainfall is not sufficient to drastically favor annuals. The continued dominance of perennials in both environments indicates that rainfall levels are low, supporting long-lived plant species that are adapted to these conditions. The dominance of perennials was agreed with Mohamed (2014), Abdelaal (2017) and Bedair *et al.* (2021).

The life form spectrum of the study area shows clear patterns of dominance, with Chamaephytes, Phanerophytes, and Hemicryptophytes being the most prevalent in both inland and coastal regions. Chamaephytes, particularly in the inland area (46.58%), thrive in the harsh, hot, and dry conditions with limited rainfall, which favor their survival. This dominance also reflects human influence and the lack of microhabitats that could support a larger proportion of perennials (Al Shaye et al., 2020). Phanerophytes and Hemicryptophytes are also present in both regions, with phanerophytes in smaller numbers and Hemicryptophytes (7.53% on the coastline and 8.22% inland) showing their ability to adapt to drought, salinity, sand accumulation, and grazing, as noted by Danin and Orshan (1990) and Danin (1996). These life forms are crucial for plant survival in such challenging environments.

The plant communities in both inland and coastal sites are influenced by physiographic features, climatic conditions, and human activities. These communities, with their unique species compositions and assemblages act as crucial bioindicators for evaluating the stability and conservation status of desert ecosystems (Abdelaal, 2017). This distinction is clearly observed through



## Floristic Composition and Edaphic Influences in the Gulf of Suez

TWINSPAN analysis, which highlights significant differences in the plant communities between inland and coastal regions. Coastal sites were grouped into seven distinct assemblages: *Haloxylon salicornicum* assemblage, *Zygophyllum coccineum* assemblage, *Zygophyllum coccineum*–*Ochradenus baccatus*–*Bassia indica* assemblage, *Trichodesma africanum*–*Zygophyllum coccineum* assemblage, *Tamarix nilotica* assemblage, *Tamarix nilotica* assemblage, and *Tamarix aphylla* assemblage. On the other hand, the inland sites were categorized into five assemblages: *Tamarix nilotica* assemblage, *Zilla spinosa* assemblage, *Launaea spinosa* assemblage, *Zygophyllum coccineum*–*Farsetia aegyptia* assemblage and the last assemblage including *Anabasis articulata*, *Anastatica hierochuntica*, *Matthiola longipetala*. So, the spatial distribution of these plant communities is closely linked to the heterogeneous topography, edaphic factors, and microhabitat conditions of the study area. Local variations in soil texture, salinity, and moisture play a significant role in shaping these assemblages, highlighting the impact of environmental heterogeneity on vegetation patterns in desert ecosystems (Abd El-Aal *et al.*, 2015).

The dominance of *Zygophyllum coccineum* and *Zilla spinosa* in these assemblages agreed with that of Abdelaal (2017) and Mashaly (1996). *Zygophyllum coccineum* dominated nearly all the assemblages of the coastline sites. Among these, Assemblage 2 exhibited the highest percentages of sand (98.1%), silt (30.5%), and calcium carbonate ( $\text{CaCO}_3$ , 26%). This observation aligns with the findings of El-Amier *et al.* (2016) who highlighted *Zygophyllum coccineum*'s remarkable ability to thrive in a variety of soil types and habitats. The plant is widely distributed across the plains and limestone wadis of the Eastern Desert, demonstrating a notable tolerance for saline soils.

The inland plant assemblages are notably dominated by many species including *Launaea spinosa* and *Farsetia aegyptia* to the prevailing soil conditions. *Farsetia aegyptia* demonstrates a positive relationship with soil properties particularly clay and sand fractions, as well as calcium carbonate ( $\text{CaCO}_3$ ) as highlighted by Abd El-Aal *et al.* (2015). This is consistent with the characteristics of assemblage 4 which is dominated by *Farsetia aegyptia* and associated with high clay content (84.8%) and elevated calcium carbonate levels (32.3%). These soil conditions provide an optimal habitat for *Farsetia aegyptia*, further emphasizing its adaptability to such specific edaphic environments.

Meanwhile, *Launaea spinosa* represents a more advanced stage of ecological succession within the inland wadi environments (Wadi Hagul). Its presence is indicative of deeper floor deposits enriched with coarse rock detritus and a higher proportion of salt deposits, reflecting the unique edaphic conditions of these inland sites (Zahran and Wills 2009). These conditions align with the highest level of electrical conductivity (EC, 10.5 dS/m) in third assemblage which was dominated by *Launaea spinosa*.

*Tamarix nilotica*, *Phragmites australis* and *Zilla spinosa* were found in most of the assemblages in both inland and coastline areas. *Zilla spinosa* is highly tolerant of drought even during extremely hot months. It responds to heat or water

stress by increasing its soluble sugar content thus creating significant osmotic potential (Salama et al., 2016). While *Tamarix nilotica* and *Phragmites australis* are known for their tolerance to salt and drought (Abd El-Ghani et al., 2014). These species share key characteristics, such as their ability to withstand extreme environmental stressors, which are the defining traits that combine both the inland and coastline assemblages. Their resilience to drought, salinity, and heat stress allows them to thrive in the challenging conditions found in both regions, contributing to their presence across various assemblages.

The coastal regions showed the presence of several introduced and invasive species. These species were *Chenopodium album*, *Chenopodium ficifolium*, *Chenopodium murale*, *Cenchrus biflorus*, *Malva parviflora*, *Melilotus indicus*, *Lysimachia arvensis*, and *Portulaca oleracea*, all of which are entirely absent from inland sites. Additionally, the presence of alien species *Solanum lycopersicum* and *Cucumis melo* which have escaped from cultivation, despite not being part of Egypt's wild flora. Their presence highlights the significant impact of human activities on local ecosystems. The introduction of these species poses a serious ecological threat by outcompeting native flora, altering natural habitats, and diminishing the genetic diversity of indigenous plants. Their proliferation is particularly concerning in arid environments, where biodiversity and natural resources are already vulnerable. This distribution pattern reflects intense human intervention along the coastline, where proximity to water sources facilitates the establishment of these species, whereas the drier inland regions experience lower levels of human-mediated introduction.

The Canonical Correspondence Analysis (CCA) of the plant species from the coastline and inland areas reveals distinct differences in the environmental factors influencing species distribution in these two habitats. In the coastline areas, species distribution was primarily influenced by high electrical conductivity (EC), sodium ( $\text{Na}^+$ ), magnesium ( $\text{Mg}^{2+}$ ), potassium ( $\text{K}^+$ ), and chloride ( $\text{Cl}^-$ ), reflecting the saline and coastal conditions. Species such as *Bassia eriophora*, *Halopeplis perfoliata*, and *Phragmites australis* were positively associated with these factors, indicating their adaptation to saline environments. In contrast, species like *Cleome amblyocarpa* and *Achillea fragrantissima* were negatively influenced by these same factors, highlighting their preference for less saline conditions. On the other hand, the inland CCA showed that species distribution was more strongly influenced by factors such as potassium, pH, calcium carbonate ( $\text{CaCO}_3$ ), and organic content which agrees with the findings of Mashaly (1996). Species like *Tamarix nilotica* and *Zygophyllum molle* thrived in areas with higher potassium and  $\text{CaCO}_3$  while species such as *Vachellia tortilis* and *Lycium shawii* were negatively affected by these same factors. The inland sites also showed a notable association between species and organic matter with plants like *Achillea fragrantissima* and *Ifloga spicata* thriving in areas rich in organic carbon. Overall, while both the coastline and inland areas exhibited distinct environmental gradients influencing plant species the coastline was more dominated by salinity and ion

concentration whereas inland species were more influenced by factors like soil pH, calcium carbonate, and organic matter content.

### Conclusion

The comparison between plant species in the inland and coastal areas of the Red Sea coastal desert shows how plants adapt to their unique environments. Coastal plants are built to handle high salinity and fluctuating moisture levels, thriving in mineral-rich soils affected by seawater. Inland plants, on the other hand, deal with extreme dryness and poor soil quality, developing ways to cope with drought, shifting pH levels, and limited organic material. Despite these differences, both ecosystems share resilience, demonstrating how desert plants can survive tough conditions. However, the presence of invasive species in coastal areas adds complexity, showing the impact of human activity on these fragile environments. Ultimately, factors like salinity, soil composition, and moisture availability shape plant communities, highlighting the importance of understanding these elements to protect and conserve desert ecosystems.

### References

- Abdelaal M, El-Shora HM & Kadhim OJ (2015). Community associates of the medicinal *Farsetia aegyptia* Turra and its soil correlates in the north-eastern desert of Egypt. *Mansoura Journal of Biology*, 40(8), 53–66.
- Abd El-Aal M, Mashaly IA, Soliman MI, Rizk RM & Elmersy MF (2019). Vegetation ecology associated with some species of family Zygophyllaceae in different biogeographic regions of Egyptian desert. *Catrina*, 19(1), 1–13. <https://doi.org/10.21608/cat.2018.6083.1008>
- Abd El-Ghani M, Salama F & Aleem M (2014). *Flora and vegetation of the Eastern Desert of Egypt*. Lambert Academic Publishing.
- Abd El-Ghani M, Bornkamm R, Nadia ES & Turky H (2015). Heterogeneity of soil and vegetation in the urban habitats of new industrial cities in the desert landscape of Egypt. *Notulae Scientia Biologicae*, 7(1), 26–36. <https://doi.org/10.15835/nsb.v7i1.9326>
- Abd El-Ghani M, Salama F, Salem B, El-Hadidy A & Abdel-Aleem M (2017). Phytogeography of the Eastern Desert flora of Egypt. *Wulfenia*, 24(1), 97–120.
- Abdelaal M (2017). Current status of the floristic composition in Wadi Hagul, northwest Suez Gulf, Egypt. *Rendiconti Lincei*, 28, 81–92. <https://doi.org/10.1007/s12210-016-0577-8>
- Al Shaye NA, Masrahi YS & Thomas J (2020). Ecological significance of floristic composition and life forms of Riyadh region, Central Saudi Arabia. *Saudi Journal of Biological Sciences*, 27(1), 35–40. <https://doi.org/10.1016/j.sjbs.2019.04.009>
- Bedair R, Ibrahim AA, Alyamani AA, Aloufi S & Ramadan S (2021). Impacts of anthropogenic disturbance on vegetation dynamics: A case study of Wadi

- Hagul, Eastern Desert, Egypt. *Plants*, 10(9), 1906. <https://doi.org/10.3390/plants10091906>
- Boulos L (1999). *Flora of Egypt, Vol. 1: Azollaceae–Oxalidaceae*. Al-Hadara Publishing, Cairo, Egypt, 419 pp.
- Boulos L (2000). *Flora of Egypt, Vol. 2: Geraniaceae–Boraginaceae*. Al-Hadara Publishing, Cairo, Egypt, 352 pp.
- Boulos L (2002). *Flora of Egypt, Vol. 3: Verbenaceae–Compositae*. Al-Hadara Publishing, Cairo, Egypt, 373 pp.
- Boulos L (2005). *Flora of Egypt, Vol. 4: Monocotyledons (Alismataceae–Orchidaceae)*. Al-Hadara Publishing, Cairo, Egypt, 617 pp.
- Boulos L (2008). Flora and vegetation of the deserts of Egypt. *Flora Mediterranea*, 18, 341–359.
- Boulos L (2009). *Flora of Egypt Checklist Revised Annotated Edition*. Al-Hadara Publishing, Cairo, Egypt, 410 pp.
- Dahmash AA (2001). *Ecological and phytosociological studies on plant communities in the Eastern Desert of Egypt*. (Ph.D. Thesis). Faculty of Science, Zagazig University, Egypt.
- Danin A (1996). Plant adaptations to environmental stresses in desert dunes. In *Plants of Desert Dunes* (pp. 133–152).
- Danin A & Orshan G (1990). The distribution of Raunkiaer life forms in Israel in relation to the environment. *Journal of Vegetation Science*, 1(1), 41–48.
- El-Amier YA, El-Shora HM & Hesham M (2016). Ecological study on *Zygophyllum coccineum* L. in coastal and inland desert of Egypt. *Journal of Agriculture and Ecology Research*, 6(4), 1–17. <https://doi.org/10.9734/JAERI/2016/22640>
- El-Amier YA, Zahran MA & Alghanoudi GA (2015). Vegetation ecology of coastal and inland parts of the deserts in Egypt. *Journal of Environmental Sciences*, 44(4), 659–675.
- El-Amier YA & Abdul-Kader OM (2015). Vegetation and species diversity in the northern sector of Eastern Desert, Egypt. *West African Journal of Applied Ecology*, 23(1), 75–95.
- Garcia-Caparrós P, Al-Azzawi MJ & Flowers TJ (2023). Economic uses of salt-tolerant plants. *Plants*, 12(14), 2669. <https://doi.org/10.3390/plants12142669>
- Hassan LM (1987). *Studies on the flora of the Eastern Desert*. (Ph.D. Thesis). Faculty of Science, Cairo University, 515 pp.
- IPNI (2023). *International Plant Names Index*. Retrieved from <http://www.ipni.org> (accessed 5 April 2023). The Royal Botanic Gardens, Kew, Harvard University Herbaria & Libraries, and Australian National Herbarium.
- Jackson ML (1967). *Soil Chemical Analysis*. Prentice-Hall, Inc., 498 pp.
- Johansen DA (1940). *Plant Microtechnique*. Tata McGraw-Hill Publishing Company Ltd., Bombay, New Delhi, 25 pp.
- Mashaly IA (1996). On the phytosociology of Wadi Hagul, Red Sea Coast, Egypt. *Journal of Environmental Sciences, Mansoura University*, 12, 31–54.
- Migahid AM (1978). *Flora of Saudi Arabia* (3rd ed.). University Libraries, King Saud University, Riyadh, Saudi Arabia.

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- Mohamed AA (2014). A study on the plant diversity in Wadi Hagul, Eastern Desert, Egypt. *Egyptian Journal of Agricultural Sciences*, 65(1), 10–20.
- Page AL, Miller RH & Keeney DR (1982). *Methods of soil analysis. Part 2*. American Society of Agronomy, Soil Science Society of America, Madison, WI, USA, 4(2), 167–179.
- POWO (2023). Plants of the World Online. Retrieved from <https://powo.science.kew.org/> (accessed 5 April 2023). The Royal Botanic Gardens, Kew.
- Richards LA (1954). *Diagnosis and Improvement of Saline Alkali Soils*. Agriculture Handbook 60, US Department of Agriculture, Washington DC.
- Salama FM, Gadallah MAEE, Sayed SAEM & Abd El-Aal AEM (2016). Adaptive mechanisms in *Zilla spinosa* and *Leptadenia pyrotechnica* plants to severe aridity in the Egyptian deserts. *Notulae Scientia Biologicae*, 8(4), 498–510. <https://doi.org/10.15835/nsb.8.4.9832>
- Salama FM, Abd El-Ghani MM, El-Tayeh NA, Galal HK, and El-Naggar S (2018). Vegetation analysis and species distribution in the lower tributaries of Wadi Qena in the Eastern Desert of Egypt. *Jordan Journal of Biological Sciences* 11(4): 407–418.
- Täckholm V (1974). *Student's Flora of Egypt*. 2nd Edition. Cairo University Press, Cairo, 888 pp.
- Tributh H (1970). Importance of extended clay-fractionation for the more precise characterization of soil minerals and their properties. *Zeitschrift für Pflanzenernahrung, Düngung und Bodenkunde* 126: 117-134.
- Zahrán MA and Willis AJ (2009). *The Vegetation of Egypt*. Vol. 2. Springer Science & Business Media.
- Zohary M (1966) *Flora Palaestina*, Part 1, Text: Equisetaceae to Moringaceae. Israel Academy of Science and Humanities, Jerusalem, 346 pp.
- Zohary M (1972) *Flora Palaestina*, Part 2, Text: *Platanaceae to Umbelliferae*. Israel Academy of Science and Humanities, Jerusalem, 656 pp.
- <https://books.google.com/eg/books?id=jzRwwAEACAAJ>